# CM100

## Control and Charge Monitoring Unit

for Particle Therapy Control Rooms

# User Manual


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## 3.1 Standards

This unit is designed for compliance with harmonized electrical safety standard EN61010-1:2000. It must be used in accordance with its specifications and operating instructions. Operators of the unit are expected to be qualified personnel who are aware of electrical safety issues. The customer's Responsible Body, as defined in the standard, must ensure that operators are provided with the appropriate equipment and training.

## 3.2 Power and Grounding

The unit is designed to operate from +24VDC power, with a typical current requirement of 1000 mA. A suitably rated power supply module is supplied as standard and is strongly recommended. Customers who make their own 24 V power provision should ensure that the supply cannot source more than 4200 mA, that it has the correct connector type, that it is rated for use in the environment, that it provides overcurrent and short circuit shutdown and that it has all necessary regulatory approvals.

A safety ground must be securely connected to the ground lug on the case.

## 3.3 Internal Battery

The unit has an internal battery that allows the unit to operate for at least 20 minutes after the power is removed. The battery is a lithium iron phosphate (LiFePO4) type, selected for its inherent safety, reliability, and low toxicity.

## 3.4 Safety considerations for the intended application

The CM100 is a component of an overall safety system for a proton therapy system. By itself, it cannot ensure safe delivery of dose. It must be connected to relevant signals and interlock systems, the configuration must be subjected to risk analysis and the connections must be checked and tested. The following are safety features of the CM100 that must be functional and used correctly. If there is any reason to suspect the features are not working as described, the proton therapy system must not be used for medical treatments until the problem is identified and resolved.

### 3.4.1 **Interlock relays**

The unit is equipped with two safety rated relays that can be used to interlock the beam. An Emergency Off Button (EMO) is provided that connects to dual parallel safety relays.

### 3.4.2 **Pulse Counting Cable Disconnect**

The TTL and fiber signals are set to be normally high. Disconnecting the cable is automatically detected by the system, opening the safety relays and placing the unit in the error state.

### 3.4.3 **Watchdog**

The unit is equipped with a watchdog timer, maintained by the ARM/Linux + PRU programs. The watchdog triggers within 2ms if the program is compromised, opening both safety relays and resetting the processor.

## 3.5 Symbols

Some of the following symbols may be displayed on the unit, and have the indicated meanings.


Direct current


Earth (ground) terminal


Protective conductor terminal


Frame or chassis terminal


Equipotentiality


Supply ON


Supply OFF


CAUTION – RISK OF ELECTRIC SHOCK


CAUTION – RISK OF DANGER – REFER TO MANUAL

# 4 Models

| | |
|---|---|
| CM100 | Control and charge monitoring unit for particle therapy. Default build is TTL on BNC for pulses and gate. |
| -QN | Configured to count fast -ve pulses on BNC input. |
| -QO | Configured to count optical pulses on ST fiber input. |
| -GO | Configured to respond to optical gate signals on ST fiber input. |
| -PM | 6U panel mounting kit. |

Example:

| | |
|---|---|
| CM100-QO | CM100 configured to count fast -ve pulses on ST fiber input. |

# 5 Scope of Supply

CM100 model as specified in your order.

PSU24-100-1R 24 VDC 100-watt power supply with Redel locking connector, rated for medical use.

USB memory stick containing:

- CM100 User manual
- Test data

OEM customers will receive only components relevant to their application.

# 6 Optional Items and related products

## 6.1 Electrometers

I128 electrometer, single high current channel and 128 strip channel current readout electronics.

F100 electrometer, single high current channel current readout electronics.

XF03 accessory board for use with the F100 electrometer in proton therapy systems.

## 6.2 Power Supplies

PSU24-100-1R +24 VDC 100W PSU (universal voltage input, plug receptacle for standard IEC C14 three-pin socket) with output lead terminated in two-pin Redel PAG connector.

## 6.3 Battery Pack

BAT24-CM100 +24 V battery pack for CM100.

## 6.4 Signal Cables and Cable Accessories

CAB-BNC-xxx-BNC cable BNC terminated both ends, RG-58.

CAB-ST-xxHCS-ST Fiber-optic cable pair 200 µm silica fiber ST terminated with color-coded sleeves, xx feet long.

## 6.5 Data Cables

CAB-RJ45-xxx-RJ45 Ethernet CAT5.

CAB-ST-xxHCS-ST Fiber-optic cable pair 200 µm silica fiber ST terminated with color-coded sleeves, xx feet long.

# 7 Intended Use and Key Features

## 7.1 Intended Use

The CM100 was designed to meet relevant requirements of IEC 60601-2-64:2014 when installed in a proton therapy treatment control room and connected correctly to other sub-systems. Its primary purpose is to provide a redundant means of recording total delivered charge, and making that data available in the event of a power outage. The CM100 accomplishes this though a battery-backed display and nonvolatile storage. In addition, the device includes the capability of counting individual spots so that it can satisfy the needs of PBS in spot-scanning mode when attached to compatible dosimetry systems.

The charge collection function is combined with a flexible set of switches that can be configured to satisfy IEC 60601-2-64:2014 with respect to hard-wired and relay-driven interfaces to arm, start, pause and stop the treatment process. Additional functions are available through the graphic touch-screen, allowing the device to be updated as new requirements arise.

The CM100 also provides an audible indicator that is proportional to the dose rate. This indicator is internal to the device but can also be transmitted to external speakers.

## 7.2 Key Features

Designed to meet the requirements of IEC 60601-2-64:2014.

Non-volatile charge recorder (> 20 minutes duration, over 30 minutes typical).

Key switch access for preparing and enabling irradiation.

Illuminated physical switches to start and pause irradiation.

Audible signal for dose being delivered.

Latching emergency stop button with direct connection to rear panel connector.

Relay to stop irradiation if total dose exceeds target plus allowed tolerance.

7” color LCD touch screen for real-time display of dose delivered, dose target and system state.

Built-in self-diagnostics.

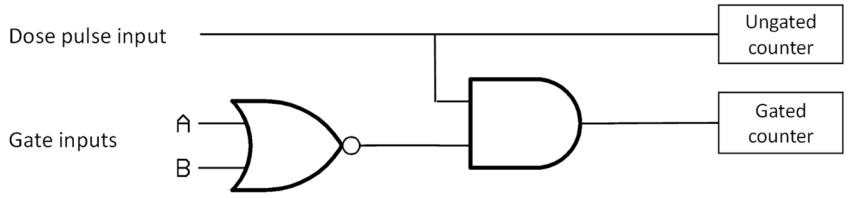
Automatic irradiation termination if internal failure detected.

Checks that critical cable connections are made.

Ethernet connectivity to compatible dosimetry and session management systems.

Maintains a record of pencil beam spot number when used with compatible dosimetry systems.

# 8 Specification

| | | |
|---|---|---|
| *Charge recording* | | |
| | Input signal type | Selectable from:<br>- TTL pulses<br>- Fiber optic 640 nm pulses<br>The dosimetry system that the CM100 works with defines the quantum of dose that corresponds to one pulse. |
| | Maximum pulse rate | 2 MHz. |
| | Dose per pulse | Configurable from 1e-5 to 1.0 MU recorded per pulse received. |
| | Counting scheme | Upwards from zero to set dose. |
| | Count limit | Automatic interlock if count reaches configurable limit, typically 120% of set dose. |
| | Counter depth | 64 bits |
| | Data retention and display | Data recorded to flash memory card.<br>CM100 display and function maintained for greater than 20 minutes after power loss using built-in re-chargeable battery pack. |
| | Gating | Two inhibit inputs to allow charge monitoring into a gated counter channel to be temporarily disabled, for example if the beam is known to be absent by other means and any apparent dose would be spurious.<br>An example is to prevent counting apparent dose from an imaging X-ray shot when the particle beam is known to be blocked by a beam stop.<br>A parallel non-gated charge monitoring counter remains active.<br>Gate inputs purchase option select from:<br>- TTL pulses<br>- Fiber-optic 640 nm pulses<br>  |
| *Audio* | | |
| | Output | Internal speaker, adjustable volume (muting not allowed).<br>Line out jack. |

| | | |
|---|---|---|
| | Sound | Selectable “tick” or “beep”. Audio frequency of beep option selectable. |
| | Scaling | Configurable pulse rate to audio tick rate mapping from 1e6 to 1e2 pulses per tick. |
| | Source | Ungated channel. |
| *Beam disable* | | |
| | Pause | Safety-rated relay (Tyco SR4) with mechanically-guided contacts and sensing of welded contacts.<br>Normally open contacts. Relay closed if Max MU threshold is not exceeded, CM100 is in READY or BEAM ON state with no errors. |
| | Overflow | Safety-rated relay (Tyco SR4) with mechanically-guided contacts and sensing of welded contacts.<br>Normally open contacts. Relay closed if Max MU threshold is not exceeded, CM100 is in READY or BEAM ON state with no errors. |
| *Processor* | | |
| | Type | TI Sitara AM335x (ARM Cortex A8) 1 GHz with dual PRU. |
| | Operating system | Debian Linux. |
| | Watchdog | Relays open (hardware action) and forced processor reset if watchdog is not tickled every millisecond. |
| *Self-test* | | |
| | Automated self-test (POST) | Automated tests of relay function, RAM and flash memory, battery function, Ethernet connection.<br>System operation prohibited if POST fails. |
| | Other tests | Tests with user prompts for button function, emergency off, audio function, key switch function, touchscreen function, fiber-optic signalling. |
| *Connectivity* | | |
| | Ethernet | Ethernet 10/100/1000 Mbps. Auto MDIX.<br>Embedded EPICS channel access server allows client software to monitor and control device function. |
| | USB | USB port for device setup and diagnostics (qualified service technician access).<br>Connecting to the USB port creates a virtual network to a host system and appears at static IP address 192.168.7.2. |
| | Dosimetry system | Direct fiber-optic communications channel to compatible pencil beam scanning scan and dose control systems to allow CM100 to |

| | | |
|---|---|---|
| | | record spot number and system state.<br>The connection is not mandatory; the CM100 will function in respects aside from spot number tracking if it is not present. |
| | Other devices | Fiber-optic communications to devices including magnetic field monitors (H20 device), power supply interfaces (M10, M40 devices) in normal or snooping mode for optional recording of data associated with beam scanning. |
| *Power* | | |
| | Power input | 24 V (+/- 2V) DC, 1000 mA typ, 1500 mA max. |
| | Battery backup | Operation of device including user interface continues for not less than 20 minutes if power is removed.<br>Alert if battery pack is missing, low performance or not in good condition.<br>Factory replaceable LiFePO4 battery assembly. |
| *Case* | | |
| | Configuration | Desk-mounting console. See figures for dimensions. |
| | Protection rating | IP34 (proof against splashed liquid). |
| | Weight | 4.5 kg (10.0 lb) |
| *Environment* | | |
| | Intended location | Particle therapy treatment rooms (one CM100 per room). |
| | Operating environment | 10 to 35 C (15 to 25 C recommended) , < 70% humidity, non-condensing, vibration < 0.2g all axes (1 to 100 Hz). |
| | Shipping and storage environment | -10 to 50 C, < 80% humidity, non-condensing, vibration < 1g all axes, 1 to 100 Hz. |
| *Controls* | | |
| | Keyswitch | Three-position switch with key retention. Positions correspond to stages in an irradiation as defined in IEC 60601-2-64: Off / Prepare / Treat.<br>Backlit labels indicate PREP and TREAT conditions.<br>Key can only be removed in OFF position. |
| | Emergency Stop | Locking push switch with visual indication of actuation. |
| | Start | Pushbutton with green illuminated bezel indicating availability to start or resume irradiation. |
| | Pause | Pushbutton with blue illuminated bezel indicating availability to pause irradiation. |

| | | |
|---|---|---|
| | User interface | 1024 by 768 backlit color LCD capacitive touch screen, 7” (17.8 cm) diagonal. |
| | Access rights | Clinical controls or service controls only enabled when authorization codes are received from a host system via Ethernet command. |
| | Processor reset | Rear panel push-button. |

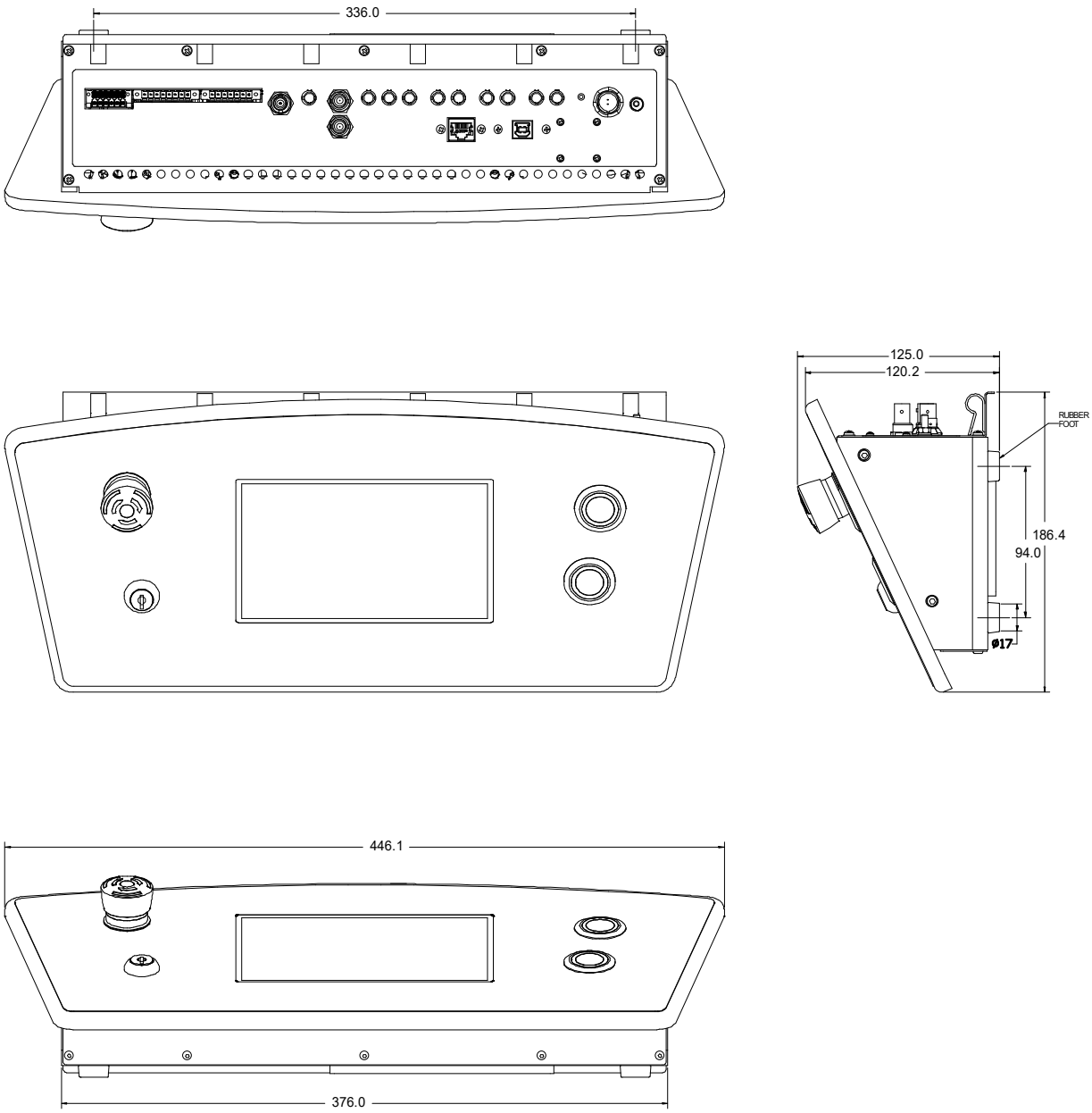



**Figure 1 - CM100 top and side views. Dimensions mm.**

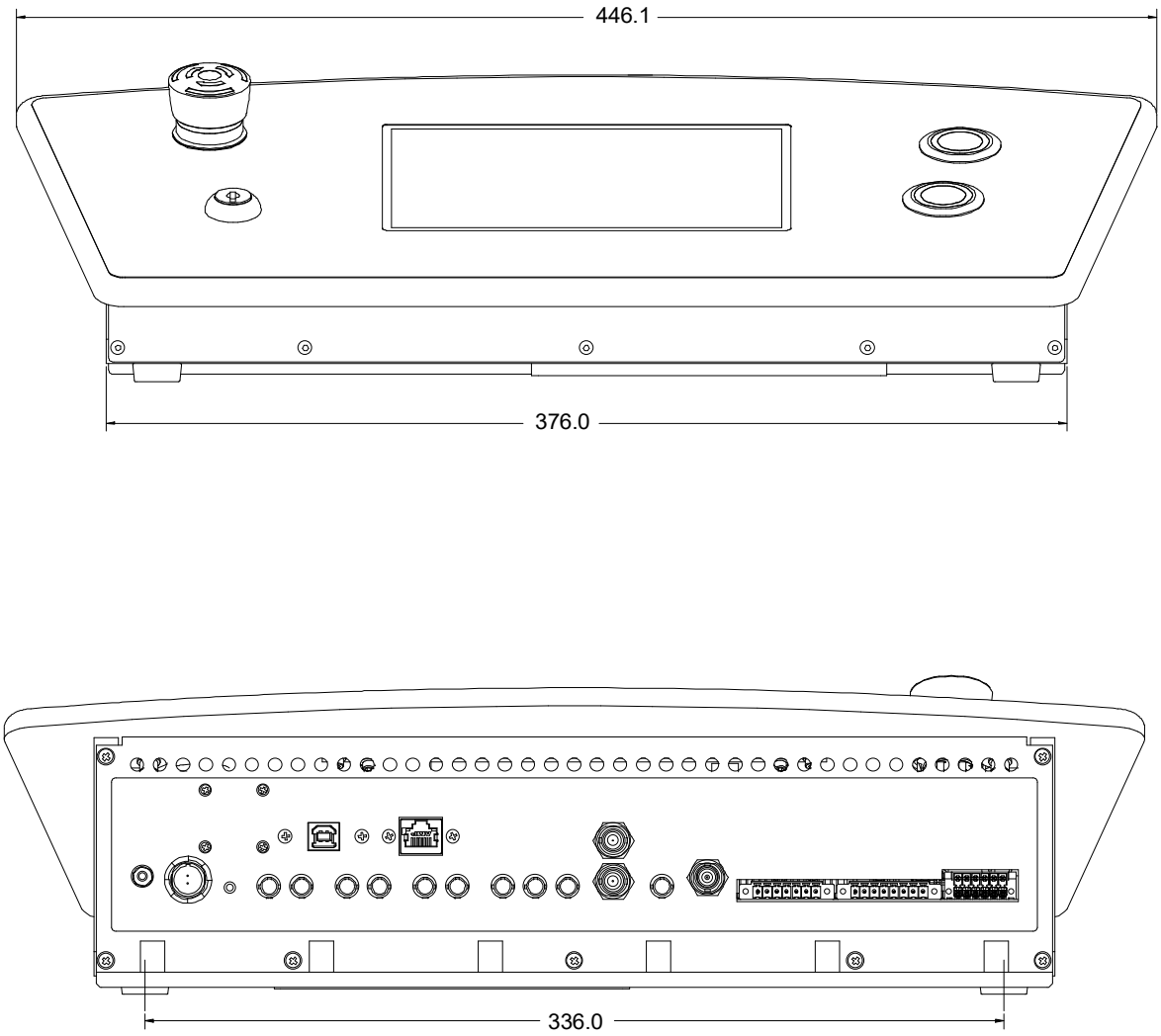



**Figure 2 - CM100 top and rear views. Dimensions mm.**

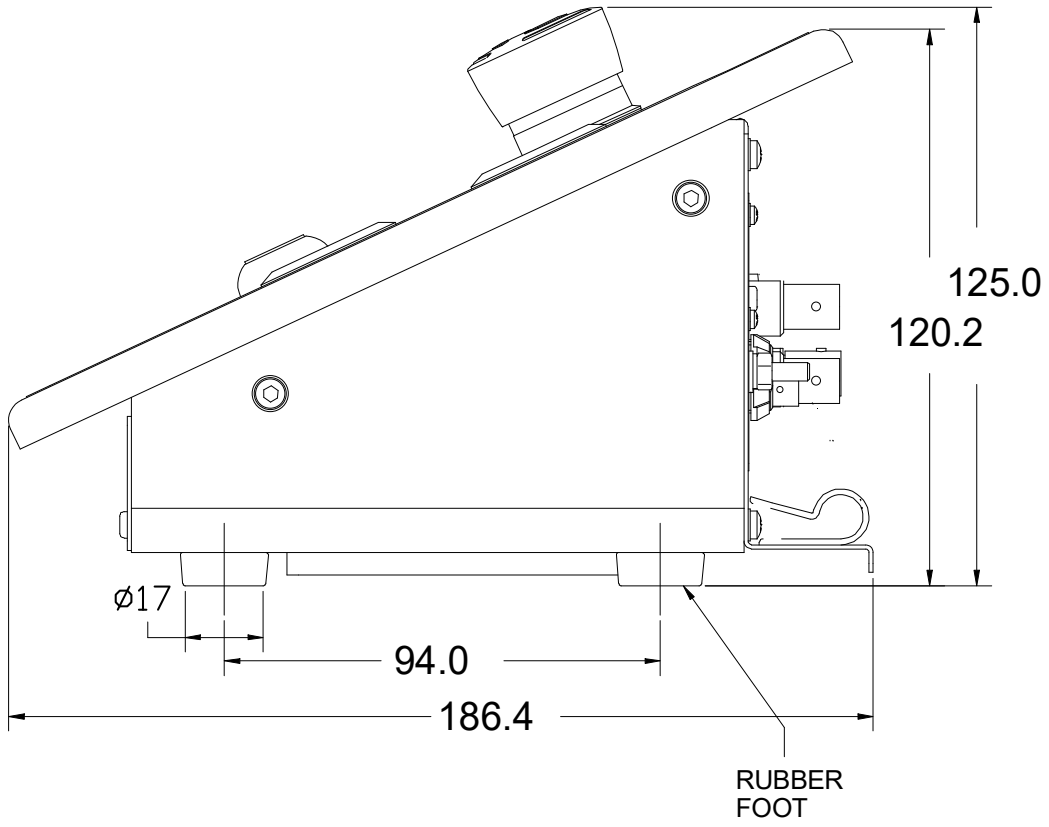



**Figure 3 - CM100 side view. Dimensions mm.**

# 9 Installation

## 9.1 Mounting

The CM100 is intended for table top use in the treatment control room of a particle therapy facility. The unit should be placed on a level surface in an area easily accessible by the therapist. The unit ideally should be located close to the computer screens (clinical user interface) that are used to set up and monitor the treatment.

The unit is designed to prevent accidental movement via a set of rubber feet on the bottom, and is also heavy enough to prevent movement under normal use.

The mounting position should allow sufficient access to connectors and cable bend radii. 60 mm minimum clearance is recommended at the front and back of the device.

Best performance will be achieved if the CM100 is in a temperature-controlled environment. No forced-air cooling is required, but free convection should be allowed around the back and sides of the case.

An optional 19” rack mount configuration is available for the CM100. Details on the rack mount configuration are available on request.

## 9.2 Grounding and Power Supply

A grounding connection is not required for the CM100.

+24 VDC power should be provided from a suitably-rated power supply with the following minimum performance:

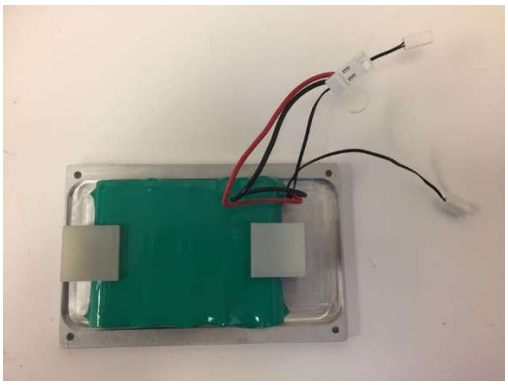
| | |
|---|---|
| Output voltage | +24 +/- 0.5 VDC |
| Output current | 1000 mA minimum, 4200 mA maximum |
| Ripple and noise | < 1% pk-pk, 1 Hz to 1 MHz |
| Regulation | < +/- 5% |

The CM100 includes an internal automatically re-setting PTC fuse rated at 1.1 A that protects the internal circuitry. The battery charging circuit is not fused, so the external 24 V power supply must provide an overcurrent shutdown facility. The PSU24-100-1R power supply provides this protection.

## 9.3 Battery

The CM100 is shipped with the battery disconnected. Use of the battery is optional if you have connected the CM100 to a secure uninterruptable power supply (UPS).

If you wish to use the internal battery, unscrew the four screws on the bottom panel of the unit.



Attach the three Molex connectors connecting the battery to the PCB. Allow the battery to charge up for four hours, then check the battery as in the section “Checking the Battery”.

## 9.4 Signal Source

The diagram below shows an example CM100 installation in schematic form.

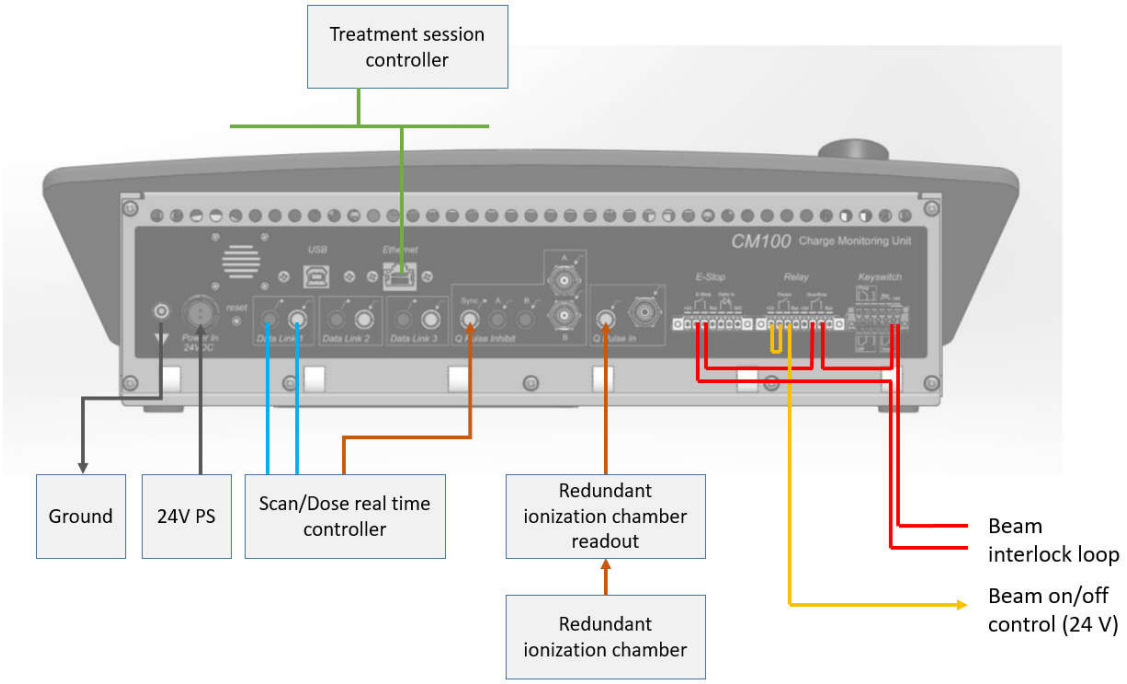



**Figure 4 - CM100 connections**

The primary function of the CM100 is to record dose from one of the electrometers monitoring the treatment via an integral plane on an ionization chamber. In the diagram the signals are transmitted as pulses via a fiber-optic cable connected to the redundant readout electronics. On some models this is connection is made with a BNC cable to a separate dedicated connector on the unit. If a BNC cable is used, it should be 50 ohm terminated to prevent signal reflections.

A separate input from one of the scan/dose real time controllers specifies whether the pulses are to be ignored, in other words, are not considered as valid particles to be measured. In the diagram this connection is made via a fiber-optic cable connected to one of the scan/dose real time controllers.

## 9.5 Interlocks

Hardware relay signals generated by the CM100 (potential-free contacts or 24 V logic) are routed directly to one or more beam abort systems. The decisions to open these interlocks are made by the CM100 depending upon the state of the key-switch, buttons, device state, and beam overflow detection logic.

## 9.6 External Audio

A speaker jack allows the CM100 to be connected to an external speaker. The speaker must be self-powered. Note that the internal speaker remains active.

## 9.7 Client

The CM100 connects to a client system via a standard CAT5 ethernet cable. Data is exchanged with the client via the EPICS protocol.

# 10 How the CM100 Works and How to Use it - An Overview

The CM100 is specially designed for particle therapy systems, providing a physical interface to the therapist with the treatment system. The CM100 was specially designed to meet certain requirements of IEC 60601-2-64:2014.

The block diagram below shows the various functions of the CM100.

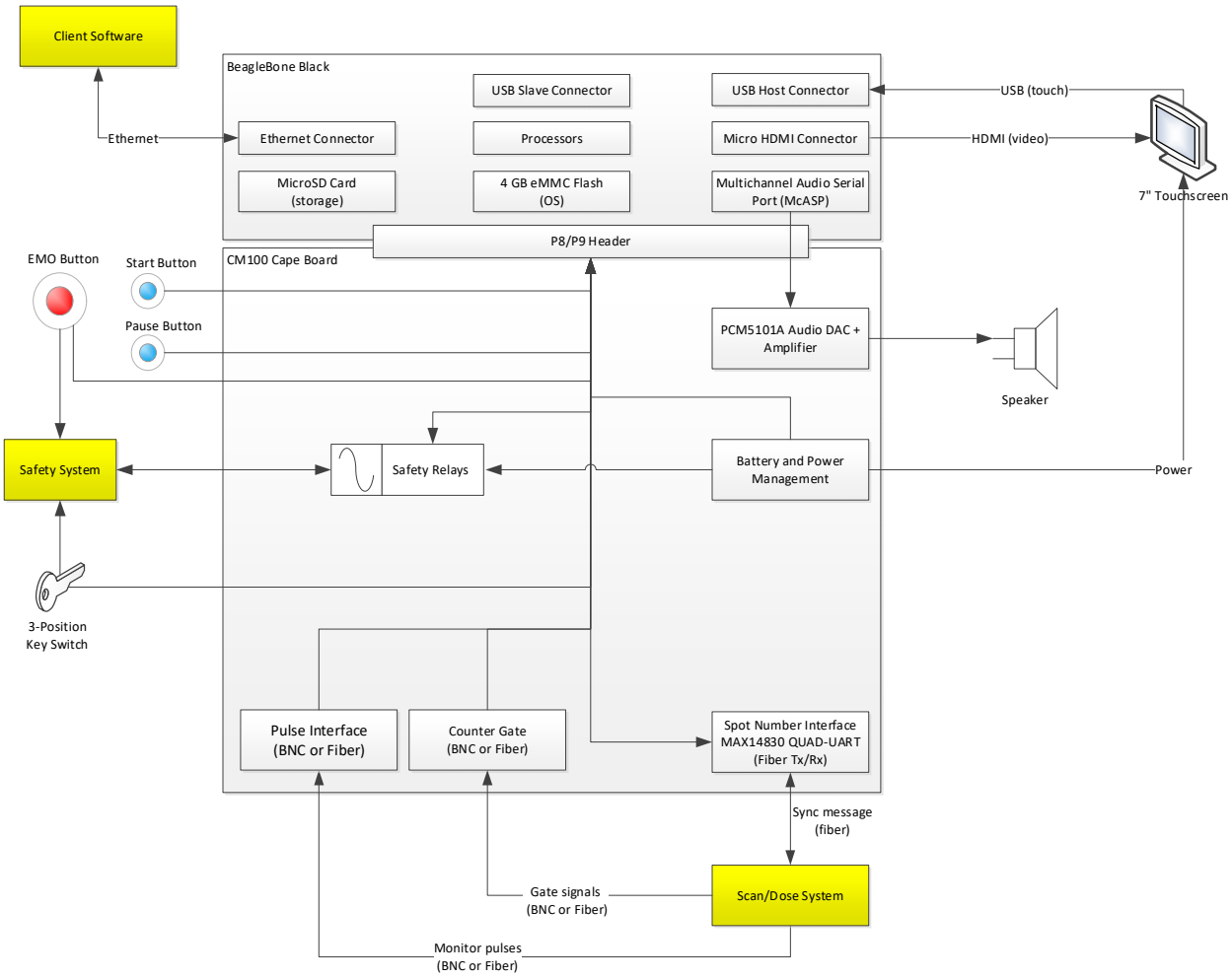



**Figure 5 - CM100 Block Diagram**

## 10.1 Touch Screen Interface

A 7” LCD color touch screen is used for the real-time display of dose delivered, dose target, spot number, and the system state. Certain setups can be modified via the touch screen interface.

## 10.2 Independent Termination System and Pulse Counting

The primary function of the CM100 is to provide an independent termination system for a particle therapy system in the case of a detected over-dose condition (see *IEC 60601-2-64:2014*

*201.10.2.101.3.1.9 Independent termination system*). This is accomplished by monitoring the applied dose and opening a hardware interlock in the event of a detected overdose.

The CM100 has an input (Q Pulse In) that counts raw pulses coming from a compatible electrometer such as the I128 or F100, where each pulse represents a known amount of dose. The pulses must be positive going minimum 1usec wide, maximum rate 2MHz. A cable-disconnect when using the BNC option will be automatically detected.

Typical particle therapy systems operate in one of two modes, Monitor Unit (MU) and Gigaproton (Gp). In MU mode a pulse would represent a fixed amount of charge as created in the ionization chamber (Coulombs), and in Gp mode a fixed number of beam particles. These values may also be corrected for temperature and pressure effects. The CM100 in any event is not concerned with the details of what the pulses mean; it merely counts what is sent to it.

The IEC standard requires that the device "*only count when LIGHT ION BEAM enters the RADIATION HEAD*". For example, the imaging process requires X-rays applied to the patient, which can be picked up by the ionization chamber. Magnetic effects from changing the scan magnet and dipole fields can also influence the readings. The CM100 provides an "inhibit" input that will inhibit the counting process for treatment particles in these cases. The CM100 accomplishes this via an "inhibit" input (Q Pulse Inhibit) that can be used to maintain a separate count of qualified pulses only. The diagram below shows this logic.

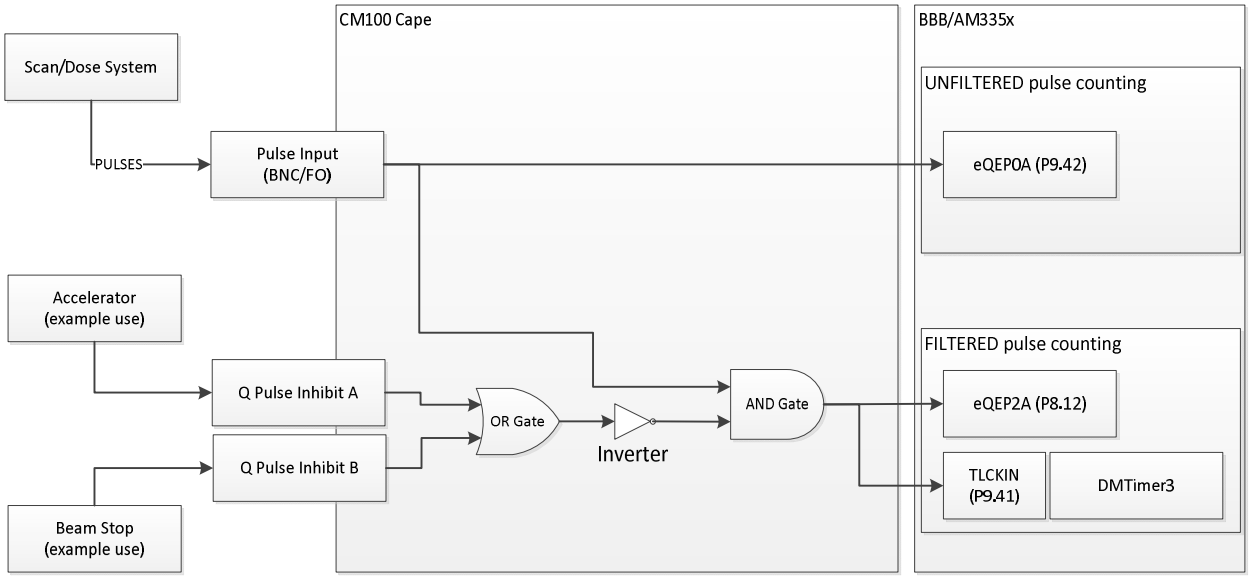



**Figure 6 - Pulse inhibit logic**

Two inhibit signals can be input to the CM100, and if either one is high then the beam is not inhibited.

The system thus maintains two counters: the total counts received by the unit since the last reset (unfiltered counter), and the counts allowed to pass through the inhibit filter (filtered counter). The filtered counter is used to see if the dose has overflowed. The unfiltered value is used to produce the audio output.

The termination logic starts by loading a target count, which is done automatically by the client via the EPICS interface. The target represents the filtered count above which the CM100 will open its "Overflow" relay to interrupt the beam and halt the treatment. This relay is normally closed, and is only opened in case of overflow or if the unit's watchdog is activated.

The filtered and unfiltered counts are published on the EPICS interface if the client wishes to display these values.

## 10.3 Audible Indicator

An audible "beep" is emitted by the CM100 proportional to the incoming unfiltered count received by the device. The beep volume can be modified in the unit's setup screens, but cannot be muted. The beep can be transmitted to an external, self-powered speaker via the external speaker jack on the unit.

## 10.4 Keyswitch

A key-switch is provided on the CM100 that can be used to interact with the workflow of the therapy session. The switch has three positions, OFF, PREP, and TREAT. The switch position impacts the state of the relays on the unit and is also reported via the EPICS interface.


**Figure 7 - Keyswitch**

A typical application would use the OFF position when the room is not active or the patient is being setup; the PREP position to load the treatment map from the planning system and to send the CM100 the overflow count; and the TREAT position to arm the system and allow the treatment to start.

The key itself provides a level of authorization to the system. The key can only be removed in the OFF state.

## 10.5 Start and Pause Buttons

Two buttons are provided that allow the therapist to start an irradiation or pause it. The buttons are surrounded by a colored ring – if the ring is green, then the button can be pressed; if the ring is red its function is suppressed.


**Figure 8 - Start and pause buttons**

## 10.6 Emergency Stop Button

A latching emergency off button (EMO) is provided to allow the therapist to interrupt the treatment. The button connects directly to the EMO connections on the back of the unit. These contacts can be connected to a means of stopping the beam production.

**Figure 9 - Emergency off button**

## 10.7 Synchronization Interface

The CM100 is capable of snooping on the Pyramid inter-controller synchronization message to determine the present spot number. This is accomplished by a fiber input located on the rear connector labeled Data Link 1. Depending upon the arrangement, the signal may want to be retransmitted out the corresponding output fiber. The spot number is displayed on the touch screen interface.

Two other fiber pairs are also located on the back, Data Link 2 and Data Link 3. These presently are not used by the system.

## 10.8 Safety Interlocks

The back of the unit has several safety interlocks that can be used to interface to the overall therapy system.

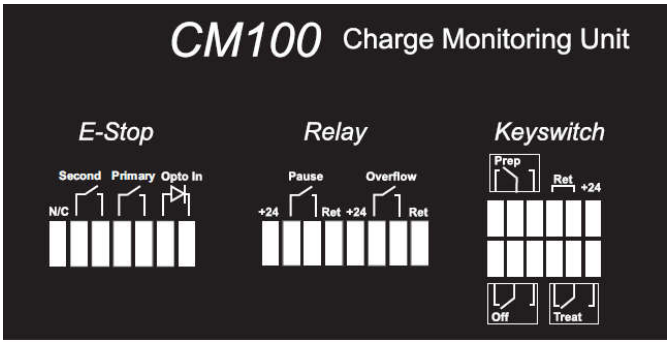



**Figure 10 - Safety interlocks – rear panel connectors**

The state of each of these relays depends upon various hardware and software states of the CM100. The states of SR4 safety relays are monitored internally to identify any malfunction such as welded contacts.

The following table is a summary of each of the interlocks and the conditions that determine the state of the contacts on the rear panel connectors:

| Interlock | Hardware conditions | Software conditions |
|---|---|---|
| E-STOP, primary (direct connection to switch) | Open EMO switch depressed. | |
| E-STOP, second(ary) (SR4 safety relay) | Open when watchdog activated. | |
| Overflow relay (SR4 safety relay) | Open when watchdog activated. | Normally closed by software; opened when gated counts detected greater than configured overflow setting. |
| Pause relay (SR4 safety relay) | Pressed state transferred to software. | Normally opened by software; closed when in treatment state and pause button press detected. |
| Keyswitch OFF | Closed when keyswitch in the OFF position. | |
| Keyswitch PREP | Closed when keyswitch in the PREP position. | |
| Keyswitch TREAT | Closed when keyswitch in the TREAT position. | |

## 10.9 Battery Backup

The unit is equipped with a lithium iron phosphate (LiFePO4) battery This type of battery was selected due to its inherent safety, reliability, and low toxicity.

The battery can provide power to the unit for at least twenty minutes in the event of a power interruption. In this event the therapist can manually record the total delivered dose and, where available, the spot number progress of the interrupted treatment.

The battery may degrade over time and should be checked periodically to determine that it is remains capable of powering the unit for at least twenty minutes. The recommended interval for this test is not longer than monthly.

## 10.10 Embedded Software

The CM100 runs the Linux operating system for the Beagle Bone Black board. The software can be updated remotely across the Ethernet interface.

# 11 Updating the CM100

The CM100 maintains its program and various options in files on its memory card. These files should be changed only by qualified service personnel. The procedure is listed here in case a change should be necessary, but it is strongly recommended that you contact Pyramid before proceeding with any change.

**ATTENTION**

If the CM100 is in use in a medical therapy system, then following any change to setup, it is mandatory that the system should be tested and re-certified as fit for its purpose by a qualified person.

## 11.1 Updating the Firmware

The firmware can be updated via two methods.

### 11.1.1 **Changing the SD card.**

The SD flash memory card can be changed, although this requires opening the unit by removal of the top panel. This will allow the operating system and running program to be updated. When this is done, it is important to preserve the System.xml file from the previous card and copy it to the appropriate location (see below). It is recommended that this procedure only be carried out at Pyramid.

### 11.1.2 **Copying program files**

The device firmware applications, including ARM/Linux service and UI, and PRUSS, can be remotely updated over Ethernet. To do this, each of the files below needs to be copied to the indicated location:

| File name | Location on CM100 | Description |
|---|---|---|
| cm100_pru0.out | opt\pyramid\cm100\bin | PRUSS 0 code, responsible for counting |
| cm100_pru1.out | opt\pyramid\cm100\bin | PRUSS 1 code, responsible for spot detection |
| cm100.exe | opt\pyramid\cm100\bin | IG2 executable running in ARM, responsible for main logic, EPICS. |
| All files | opt\pyramid\cm100\Debug | GUI |

## 11.2 System.xml

The System.xml file contains important setups relating to the performance of the CM100. This file should generally be changed under the guidance of Pyramid and we recommend contacting us before proceeding. Making incorrect entries can materially affect the performance of the unit.

### 11.2.1 **Editing the File**

To edit the file, perform the following steps:

1. The CM100 must be powered and on the network.
2. Find the **IP address** on the CM100 under **Setting->Network Settings**. Here we will assume the IP address is **192.168.100.123**
3. Access the file using the Windows Explorer at address \\192.168.100.123\bbbfilesystem\opt\pyramid\cm100\config.
4. Edit the file as needed and save back to the same location.
5. Restart CM100 using reset button on back of device

### 11.2.2 **Attributes that can be Changed**

The following attributes only should be changed:

| Node | Attribute | Description |
|---|---|---|
| cm100state | userunits | MU – monitor unit mode.<br>Gp – Gigaproton mode. |
| | spotcheck | true – enable spot display and sync checking during treatment<br>false - disable |
| pulsecounter | pulsespertick | The number of unfiltered pulses that corresponds to a single audio beep. |
| | tonetickfreq | The frequency of the beep sound in Hz. |
| | prescaler | Relates the number of physical pulses to a single MU or Gp on the display. |

## 11.3 Changing IP Address

The IP address can be changed by editing the ethernet communications file **/etc/network/interfaces**. In this file, you can change the primary network interface called **eth0**.

A static or dynamic IP can be set by using one of the following two lines:

```
iface eth0 inet dhcp          // will give it a DHCP address.
iface eth0 inet static        // will give it a static address.
```

If using a static IP, you must follow that line with the following lines:

```
address 192.168.100.123
netmask 255.255.255.0
gateway 129.168.100.1
```

To activate the new settings, SSH into the device and run

```
ifdown eth0
ifup eth0
```

Otherwise, restart the CM100 using reset button on the back of device.

## 11.4 Serial Number

The CM100 serial number is kept in file **\opt\pyramid\cm100\Debug\Serial.txt**. Do not modify this file.

## 11.5 Loopback Address

The CM100 loopback address is kept in file **\opt\pyramid\cm100\Debug\IPAdress.txt**. Do not modify this file.

# 12 State Machines

The CM100 maintains two state machines that are used to control the device process workflow, an operational and a functional state. These states are reflected on the touchscreen interface and are also transmitted via the EPICS interface.

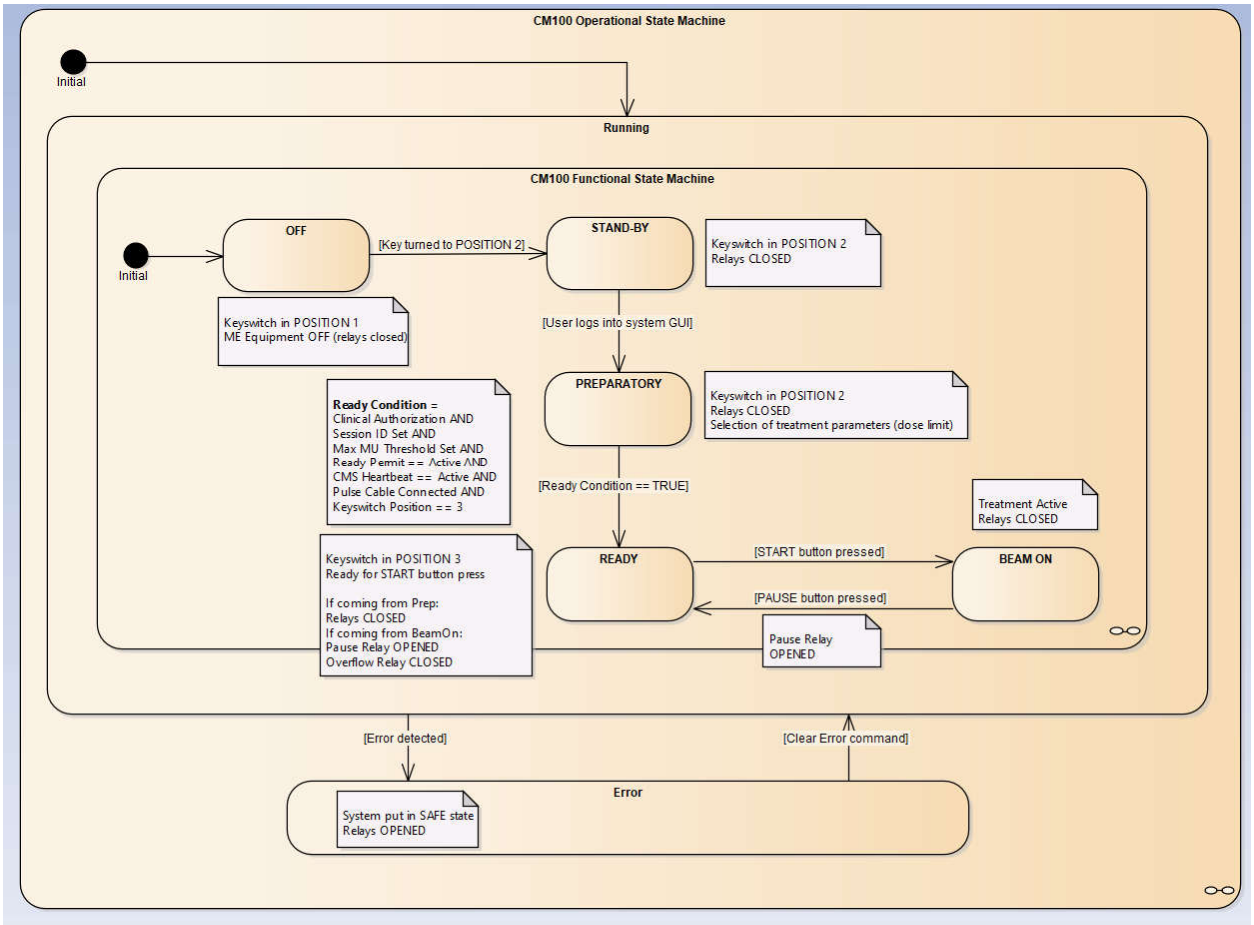



**Figure 11 - CM100 state machine**

## 12.1 Operational State Machine

The operational state machine reflects the operating state of the device.

| State | Description |
|---|---|
| Running | The CM100 is running normally with no errors. |
| Error | The unit is in the error state, which occurs due to the following conditions:<br>- Max MU/Gp threshold exceeded<br>- Emergency Stop button latched<br>- Watchdog timeout in CM100 processor |

| | |
|---|---|
| | - Pulse counter fail in BEAM ON state<br>- Max MU threshold invalid in BEAM ON state<br>- Pulse input cable-disconnect detected in BEAM ON state (BNC only)<br>- Fiber-optic communication error detected in BEAM ON state<br>- Host system communications synchronization heartbeat not present in BEAM ON state (if enabled)<br>- Spot sequence error detected (spot option must be active) |

**Figure 12 - CM100 operational states**

The operational state is determined by several inputs, including the hardware itself and state information received over the EPICS interface. The following table summarizes the state requirements:

| State | Key switch | Start button | Pause button | CMS heart beat | Ready permit | Clinical auth. | Max count and session ID | Overflow relay state | Pause relay state |
|---|---|---|---|---|---|---|---|---|---|
| Running | Any | Any | Any | Any | Any | Any | Any | Closed | Closed |
| Error | Any | Any | Any | Any | Not granted | Any | Not set | Open | Open |

**Figure 13 - Operation state conditions**

## 12.2 Functional State Machine

Following is a list of CM100 functional states:

| State | Description |
|---|---|
| Off | Keyswitch in OFF position. |
| Standby | Keyswitch in PREP position. Waiting for user authorization. |
| Preparatory | Keyswitch in PREP position. External particle therapy system and user preparing to treat. |
| Ready | Keyswitch in TREAT position. Waiting user start button press. |
| Beam On | Keyswitch in TREAT position. System is executing a treatment. |

**Figure 14 - Functional states**

The functional state is determined by several inputs, including the hardware itself and state information received over the EPICS interface. The following table summarizes the state requirements:

| State | Key switch | Start button | Pause button | CMS heart beat | Ready permit | Clinical auth. | Max count and session ID | Overflow relay state | Pause relay state |
|---|---|---|---|---|---|---|---|---|---|
| Off | OFF | Not latched | Not latched | CMS heart beat | Not granted | Not granted | Not set | Closed | Closed |
| Standby | PREP | Not latched | Not latched | Any | Any | Not granted | Not set | Closed | Closed |
| Prep | PREP | Not latched | Not latched | Any | Any | Granted | Any | Closed | Closed |
| Ready | TREAT | Not latched | Any | Active | Granted | Granted | Set | Closed | Closed |
| Beam On | TREAT | Latched | Not latched | Active | Granted | Granted | Set | Closed | Closed if coming from Prep state.<br>Open if coming from BeamOn state. |

**Figure 15 - Functional state conditions**

# 13 User Interface

The CM100 has a 7” color touchscreen that provides a graphical user interface for the therapist. The touch screen allows the therapist to navigate screens and set certain parameters. The home screen after boot-up is shown below.

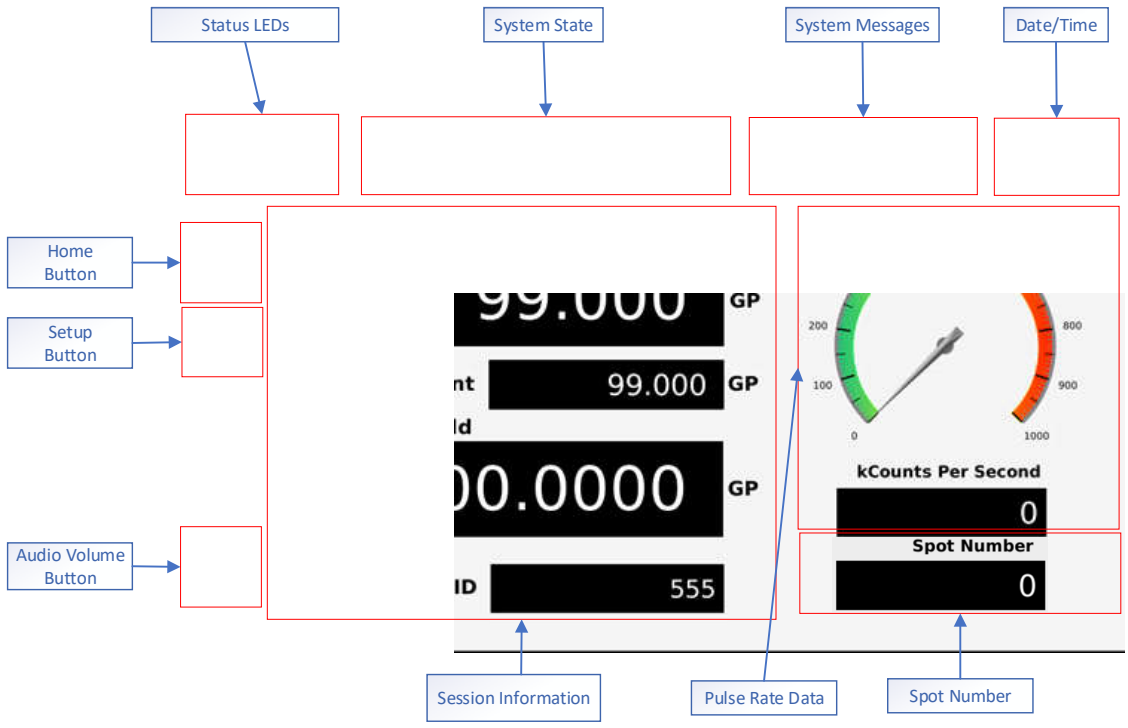



**Figure 16 - Home screen**

## 13.1 Status LEDs

### 13.1.1 **AC**

The *AC* LED shows the state of the AC power. When green, power is plugged in, when red power is disconnected.

### 13.1.2 **CMS**

The *CMS* LED is lit when the CMS is properly loaded and running. This module is necessary when the CM100 is operated in conjunction with the Pyramid Scan/Dose system.

#### 13.1.3 **Cable**

The *Cable* LED is lit when the pulse counting cable is properly connected. The device can detect cable disconnect as one of its safety features. The cable must be connected for normal operation.

## 13.2 System State

This section displays the system state, which can take on the following values:

| State | Description |
|---|---|
| Off | Keyswitch in OFF position. |
| Standby | Keyswitch in PREP position. |
| Prep | Keyswitch in PREP position. |
| Ready | Keyswitch in TREAT position. |
| Beam On | Keyswitch in TREAT position, treatment is active. |

## 13.3 System Messages

The CM100 will display helpful messages and errors in this location from time to time.

## 13.4 Date/Time

This section displays the system date and time, and is only displayed if enabled in the Settings setup screen.

## 13.5 Home Button

The *Home* button returns the software to the home page, as shown above. This can be pressed while on any other screen to return home.

## 13.6 Setup Button

The *Setup* button gives access to the setup menu, shown below. Some parameters can be changed on these setups, others can only be viewed.

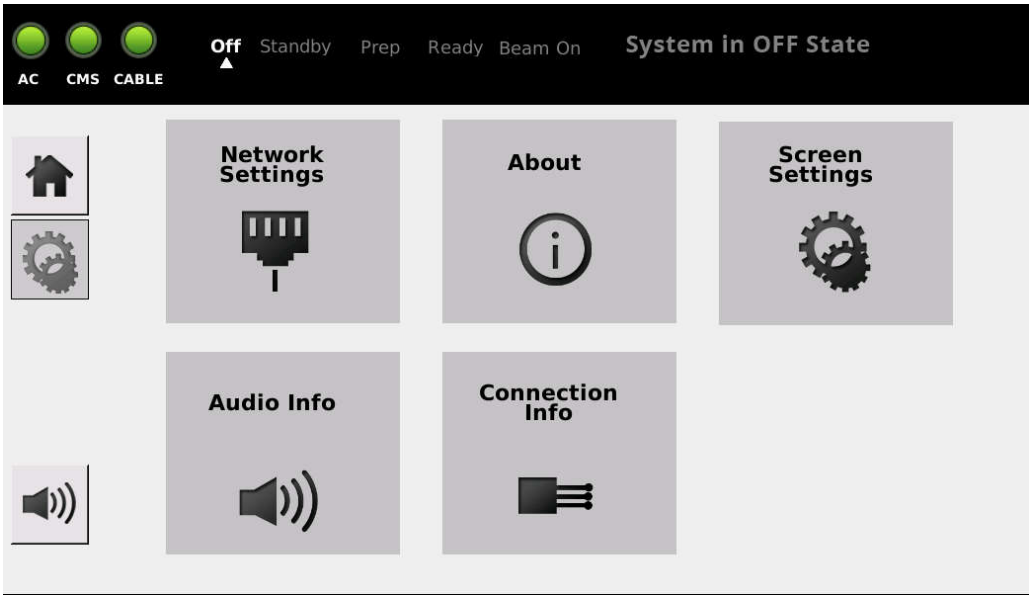



**Figure 17 –Setup menu**

Each button on the screen can be pressed to view the indicated setup or information page.

### 13.6.1 **Network**

The *Network Settings* button allows the unit's IP address, subnet mask, and default gateway to be displayed. These settings can only be changed by modifying the unit's XML file, described in a separate section of this manual.

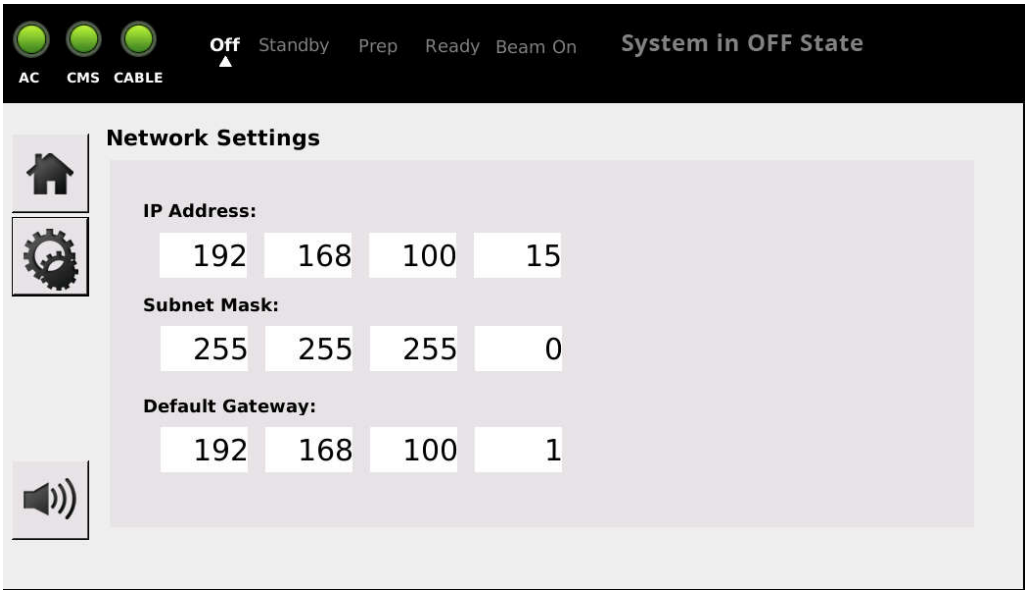



**Figure 18 - Network settings page**

### 13.6.2 **About**

The *About* page give information about the version that is installed in the device.

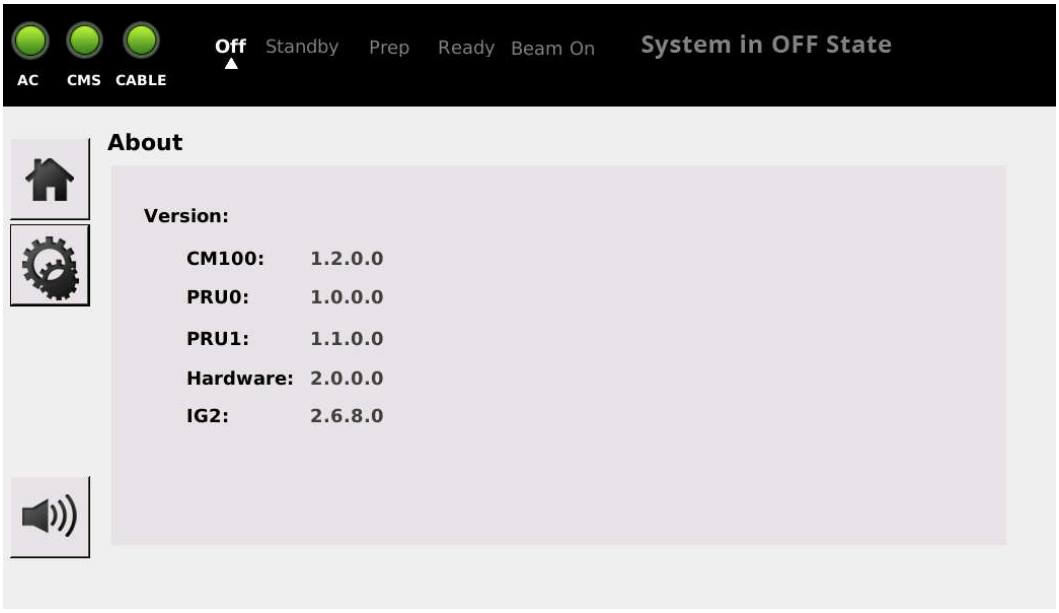



**Figure 19 - About screen**

The versions displayed are:

- CM100 – Main software version for the device
- PRU0 – Sub-processor used to handle counts and scaling
- PRU1 – Sub-processor used to handle spot count information from synchronization message.
- Hardware – the version of the hardware (PCB).
- IG2 – library used to transmit data via EPICS.

### 13.6.3 **Screen settings**

The *Screen Settings* page modifies the visual behavior of the screens.

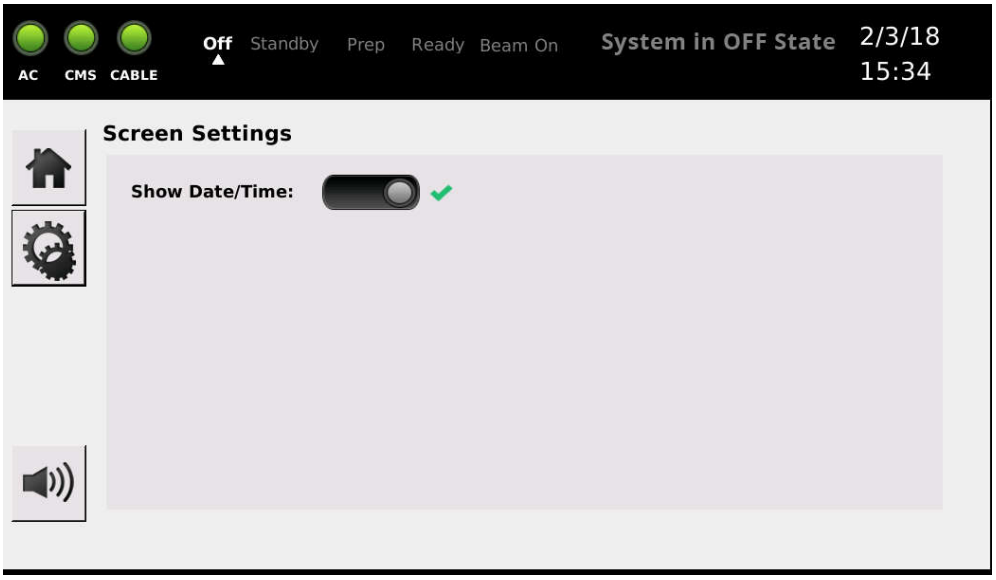



**Figure 20 - Screen settings**

The following options are available:

- Show Date/Time – if enabled displays the date and time at the top right of the screen.

### 13.6.4 **Audio settings**

The *Audio Settings* page allows settings relating to the audio output to be modified and displayed.

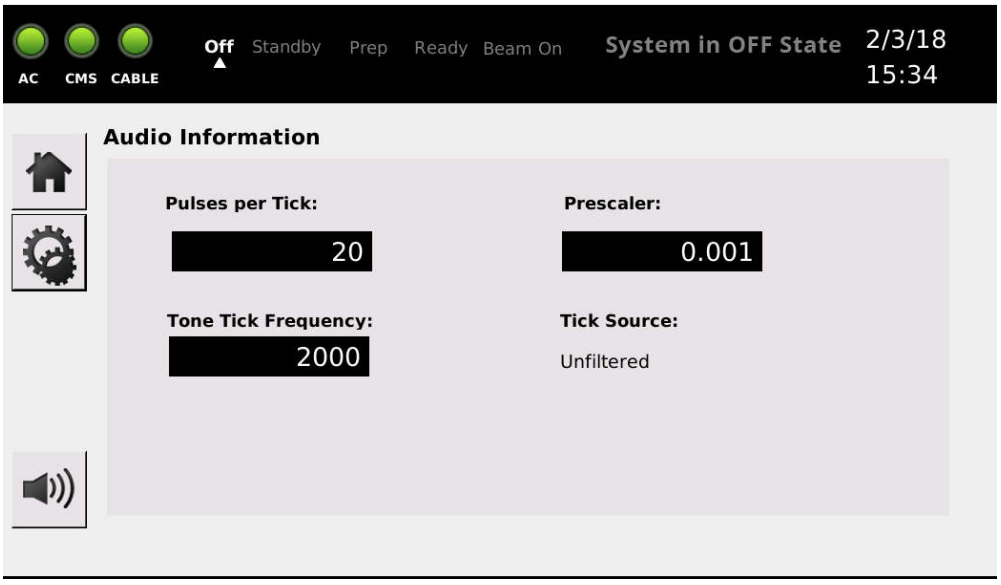



**Figure 21 - Audio information**

The following options are available (all read-only):

- Pulses per Tick – the number of detected unfiltered pulses that cause a single beep to be output.

- Tone Tick Frequency – The frequency of the tone emitted by the CM100 in Hz.
- Prescaler - Relates the number of physical pulses to a single MU or Gp on the display.
- Tick Source – The input associated with the tick, filtered or unfiltered.

### 13.6.5 **Connection settings**

When the *Connection Settings* button is pressed, the settings of the dip switches located on the bottom of the unit are displayed (see section 15.2.1). The settings of fiber vs. BNC for the pulse counting and inhibit A and B connections, and the disconnect method and mode are displayed.

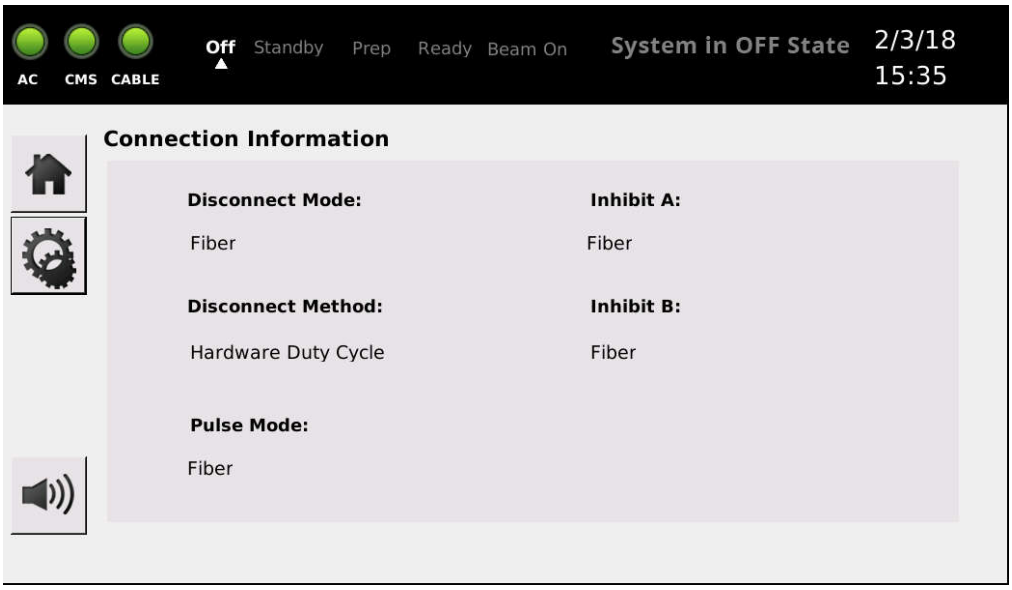



**Figure 22 - Connection settings**

## 13.7 Audio Volume

When the *Audio Volume* button is pressed, a popup will appear that allows the volume to be increased or decreased. The sound cannot be completely muted, however.

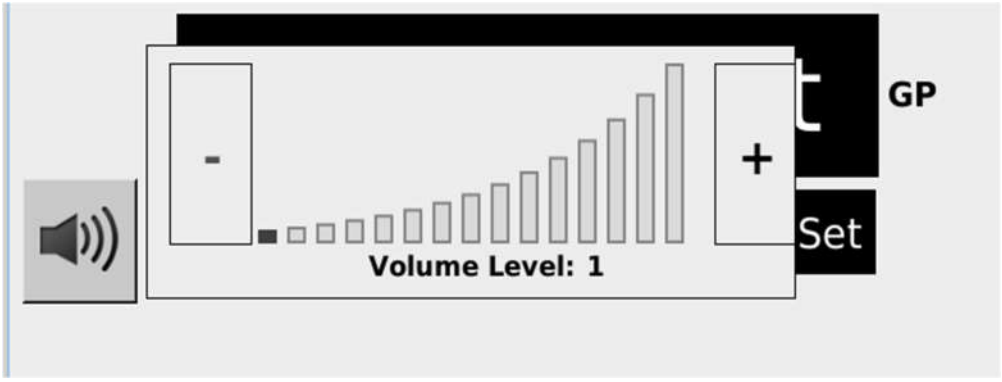



**Figure 23 - Audio volume**

## 13.8 Session Information

Specific information relating to the session is included in this section.

### 13.8.1 **Count total**

The *Count Total* field displays the filtered count in Gp or MU., that is, the count after filtering according to the pulse inhibit gate.

### 13.8.2 **Unfiltered count**

The *Unfiltered Count* field displays the unfiltered count in Gp or MU., that is, the count received by the device irrespective of the pule inhibit gate.

### 13.8.3 **Count threshold**

The *Count Threshold* field is the threshold of filtered counts above which the CM100 will open the overflow interlock and signal an error. This value is set by the client software over the EPICS interface.

### 13.8.4 **Session ID**

The *Session ID* field is a unique identifier associated with a treatment. This value is set by the client software over the EPICS interface.

## 13.9 Pulse Rate

The *Pulse Rate* section displays the rate of dose delivery. A meter shows this graphically, as well as a numeric value.

## 13.10 Spot Count

The *Spot Count* field is displayed only if Spot checking is established in the setup. This value will be the spot number known across all energy layers.

## 13.11 Error Messages

The following error message can be displayed by the CM100:

| Code | Text | Description |
|---|---|---|
| 300 | `MU(Gp) threshold violation` | Detected filtered pulses exceeds the MU or Gp threshold transmitted by the client. |
| 301 | `EMO button pressed` | The EMO button was depressed. |
| 302 | `PRU ACK is NOT active` | The PRU sub-processor is not active (fatal error). |

| | | |
|---|---|---|
| 303 | PRU heartbeat not active | The PRU sub-processor heartbeat is not found (fatal error). |
| 304 | Counter hardware failure | The counter hardware has failed (fatal error). |
| 305 | Corrupt MU threshold | The MU threshold has been found to be corrupted. |
| 306 | Pulse cable disconnected | The pulse counter cable has been detected as disconnected. |
| 307 | CMS communication failure | The CMS client program communication has failed. |
| 308 | Keyswitch moved during BeamOn state | The keyswitch was moved during the treatment state, causing the session to terminate. |
| 309 | Timeout enabling PRU threshold check | An error was detected while setting the max threshold check. |
| 310 | Fiber spot error | Spot display has been enabled, and during the treatment the spot synchronization message was not detected as necessary. |
| 311 | Power disconnected | Power was disconnected while the unit was in the Beam On state. |
| 400 | processOpState() unknown state | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |
| 401 | processIntFuncState() unknown state | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |
| 402 | processOnState() unknown state | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |
| 403 | processPrepState() unknown state | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |
| 404 | processTreatState() unknown state | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |
| 405 | setOpState() unknown state | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |
| 406 | setIntFuncState() unknown state | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |
| 407 | setOnState() unknown state | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |

| | | |
|---|---|---|
| 408 | `setPrepState() unknown state` | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |
| 409 | `setTreatState() unknown state` | This error should not normally occur. Please contact Pyramid if one of these errors occurs. |
| 500 | `keyswitch not in prep state when required` | The keyswitch should be in the Prep state. |
| 501 | `control system paused, waiting for resume` | This error is normally not propagated to the GUI. |
| 502 | `waiting on control system ready permit` | This may occur when the Ready Permit is revoked by the client. |

The error messages will be displayed with the error number across the entire portion of the screen. The user will need to move the keyswitch back to the PREP position and press the CLEAR button to continue.


**Figure 24 - Error message display and CLEAR button**

# 14 Example Use Case

Specific use of this device in the client system is flexible depending upon the configuration. The sequence diagram below shows a typical use case for the device.

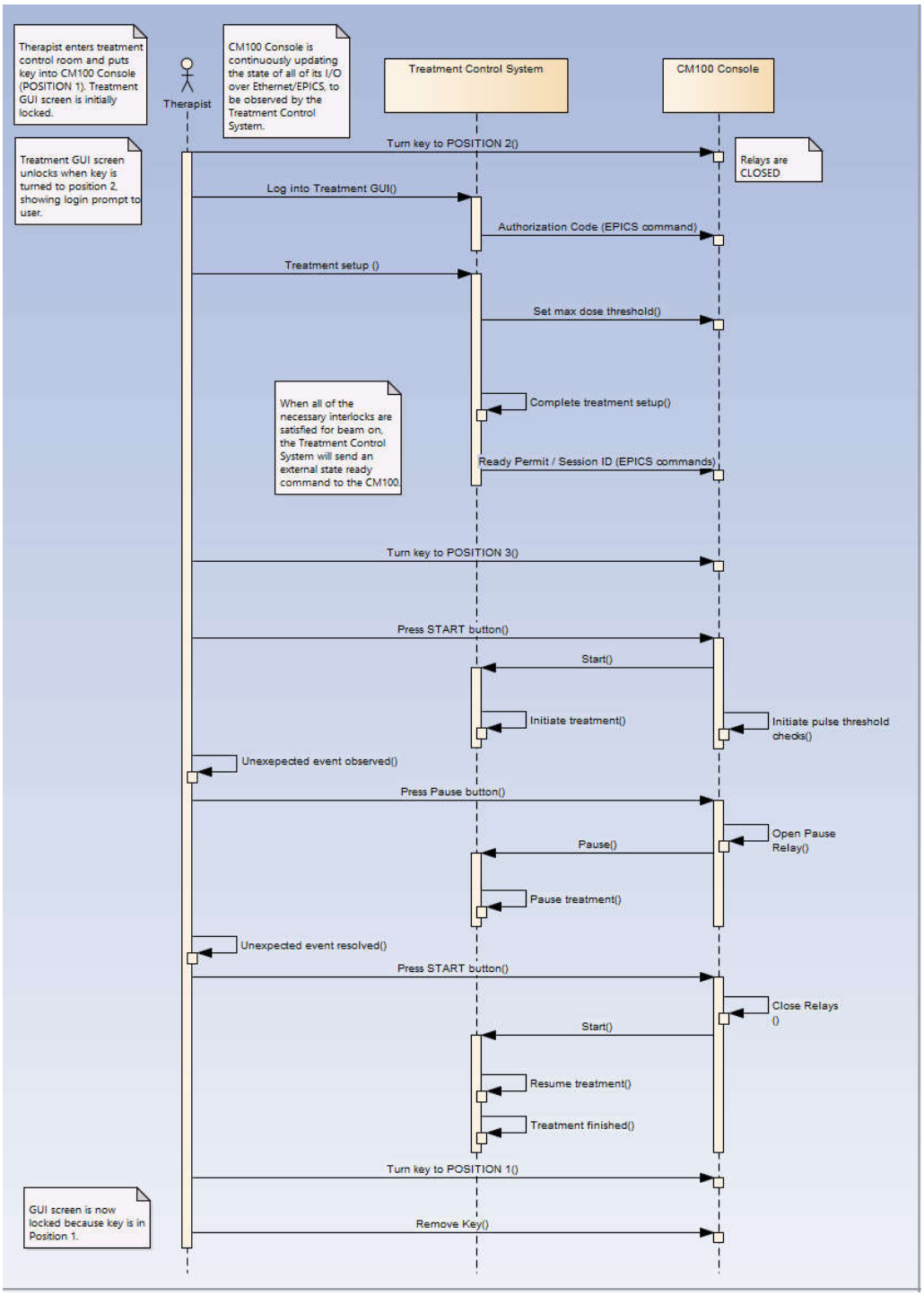



**Figure 25 - Sample sequence for CM100 use**

The sequence shown above shows a typical sequence that is used demonstrating interaction between the therapist, the CM100, and the treatment control system. The specific details of this sequence will be determined by the therapy system manufacturer.

## 14.1 Off

The system boots up in the *Off* state, waiting for action from the therapist and the client system.

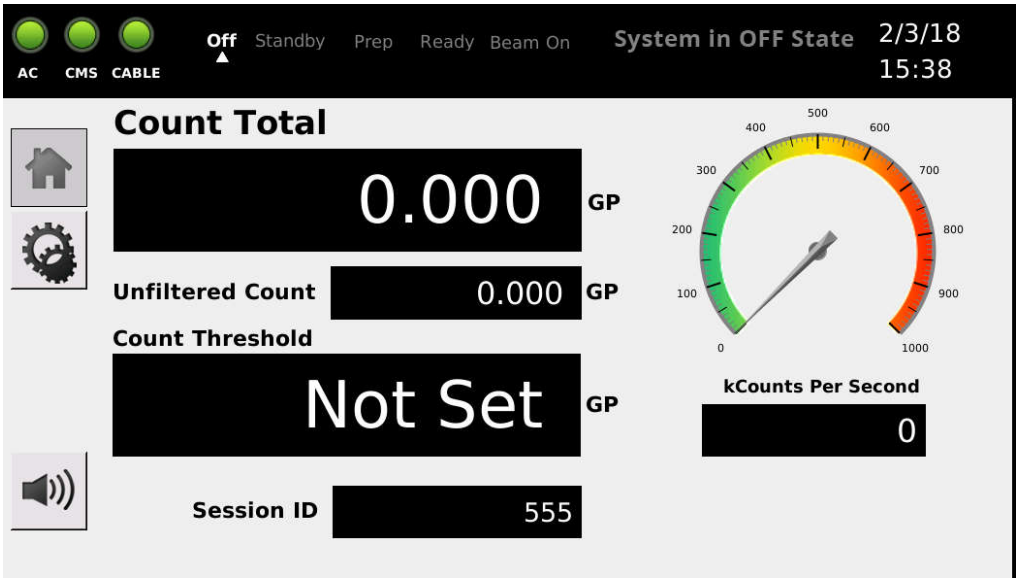



**Figure 26 - CM100 in the Off State**

## 14.2 Standby

The first step required to prepare for treatment requires that the therapist (insert and) switch the key to the PREP position. This transitions the CM100 to the *Standby* state, ready to accept authorization from the client over the EPICS interface. A reminder message is displayed in the message area.

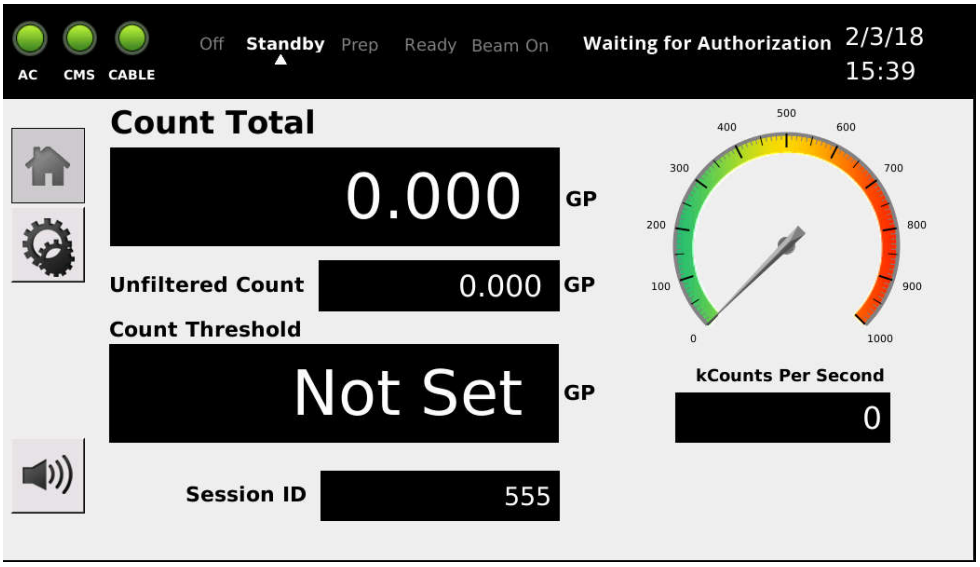



**Figure 27 - CM100 in the Standby state**

## 14.3 Prep

Once the authorization message is sent from the client, the system transitions to the *Prep* state. The client now must load the following information over the EPICS interface to the CM100:

- Session ID – a unique numeric identifier associated with the treatment.
- Count Threshold – total count (in MU or Gp) above which the overflow relay will open during the treatment, should the detected filtered count exceed this value.
- Ready Permit – standard permit to authorize treatment.

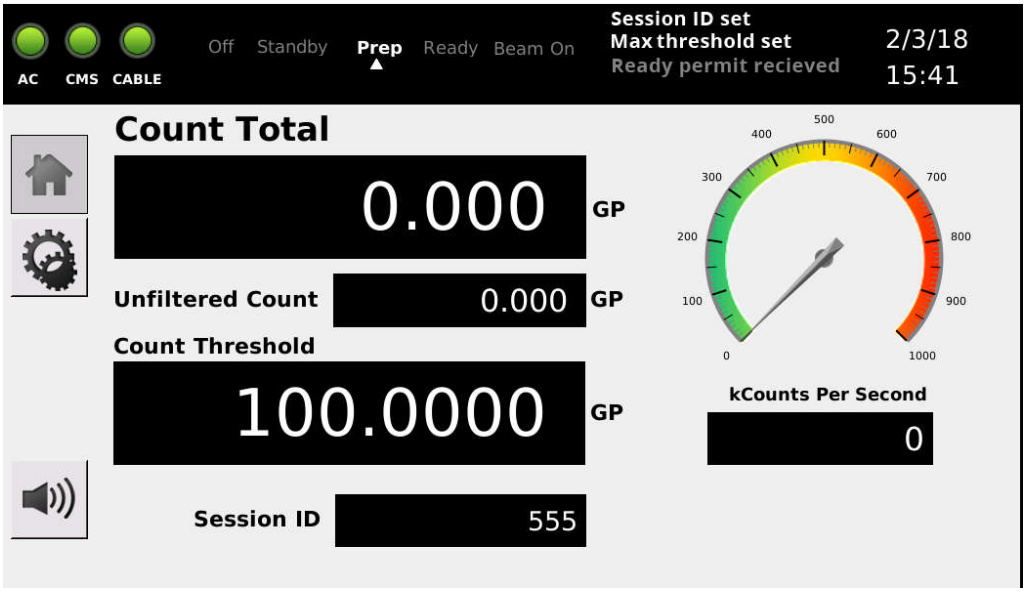



**Figure 28 - CM100 in Prep state**

The message area shows which of these items have been received by lighting up the item. In the above example the Session ID and Count Threshold (Max) have been set and the system is still awaiting the Ready permit. The ready permit should only be transmitted after the session ID and max threshold have been sent, as well as any other conditions deemed necessary by the client system.

When all three parameters have been received, the CM100 displays the message “Turn Keyswitch to ‘TREAT’ informing the therapist of the next step. The TREAT label on the key switch will also be blinking at this point.

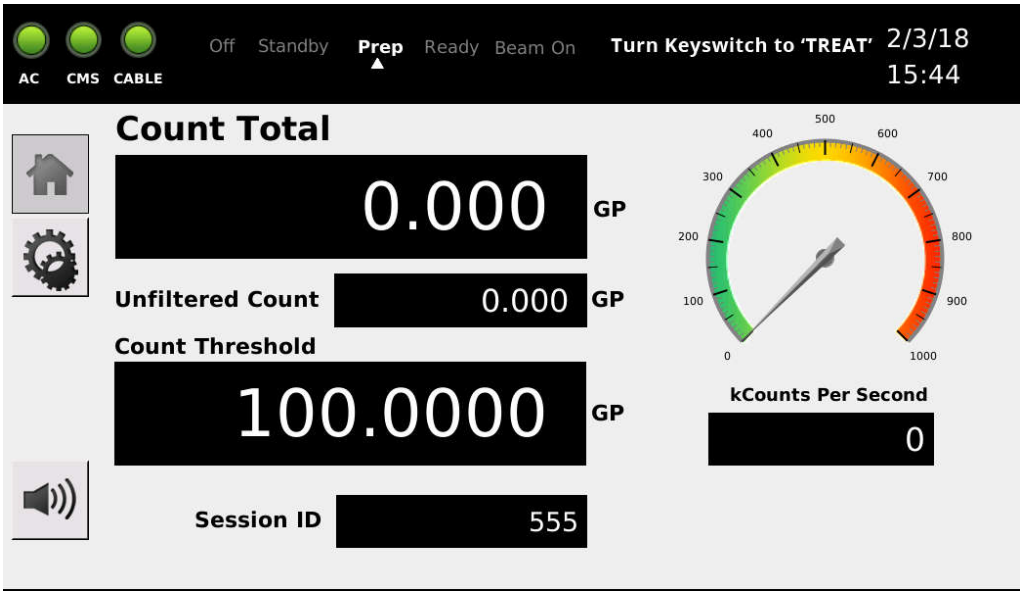



**Figure 29 - CM100 in Prep state ready to transition to Treat state**

## 14.4 Treat

Once the keyswitch is turned to the TREAT position, the CM100 enters the *Treat* state.

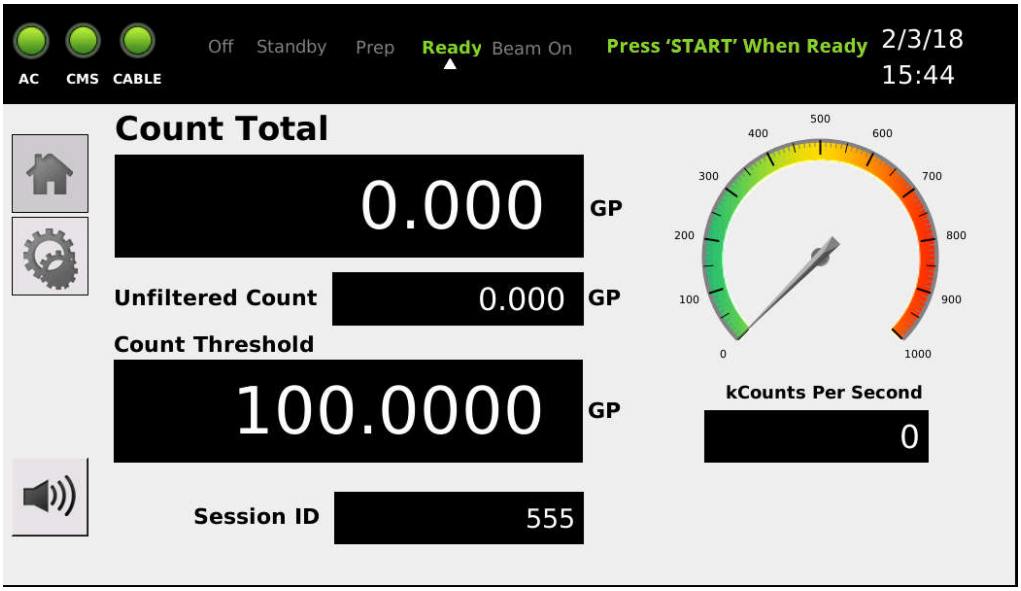



**Figure 30 - CM100 in Ready state**

The ring around the Start button should be flashing green at this point, signaling to the therapist that the treatment can be started by pressing this button.

## 14.5 Beam On

After the Start button is pressed, the CM100 enters the *Beam On* state. The ring around the Pause button should flash blue, indicating that the treatment can be paused at any time. When beam is present the CM100 should begin to read pulses, displaying them in the Count Total and Unfiltered Count fields (note that these fields are always active, even when not in the Treat state).

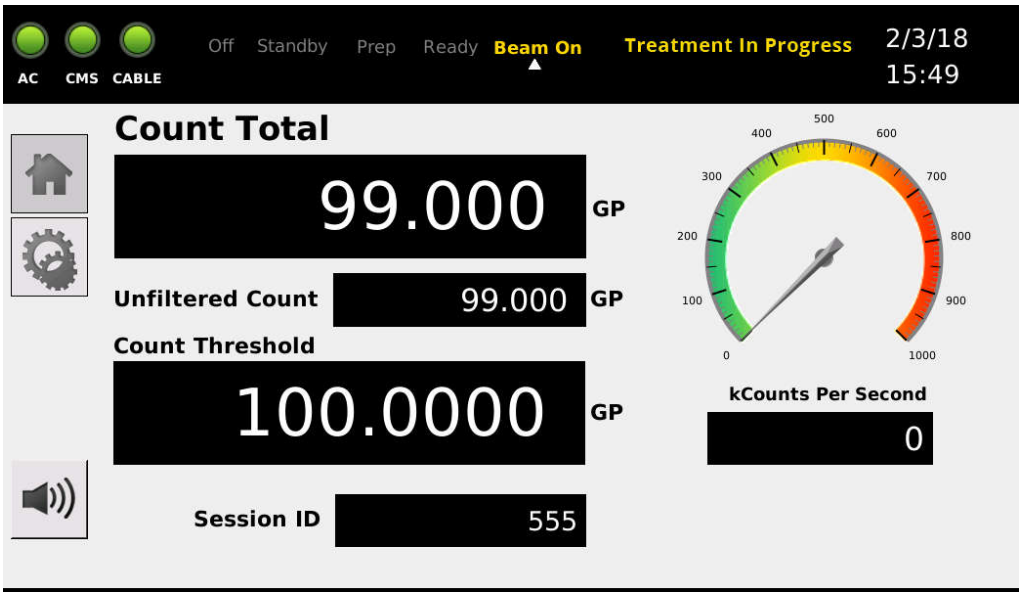



**Figure 31 - CM100 in Beam On state**

## 14.6 Treatment Complete

The client system signals the CM100 when the treatment is completed over the EPICS interface. When this occurs, the system goes back to the *Prep* state, retaining all information settings from the session.

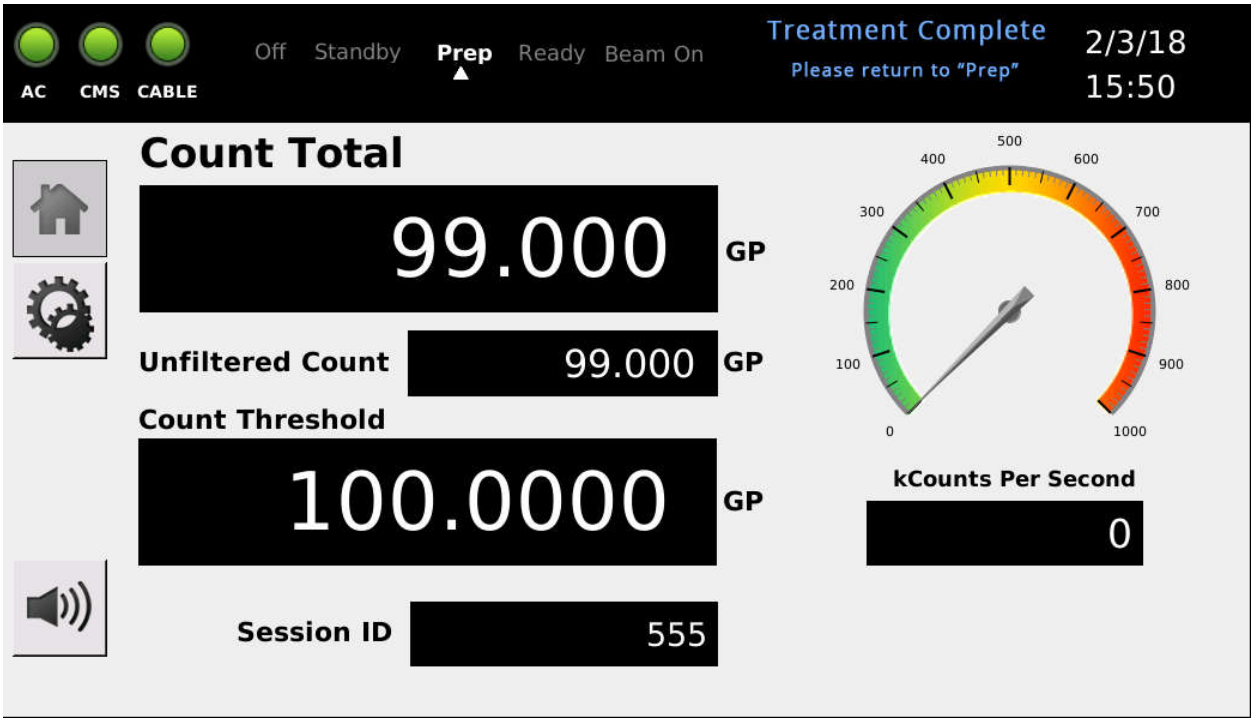



**Figure 32 - CM100 when the treatment is completed**

After turning the keyswitch back to PREP, the ready permit is automatically revoked by the CM100. The client system should enforce at this point the conditions needed to start a new session, including sending a new session ID and Max threshold.

## 14.7 Pausing an Ongoing Treatment

The therapist can press the Pause button during the Beam On state at any time, pausing the treatment. In this case the Start button will flash green, indicating that the treatment can be re-started.

## 14.8 EMO Pressed

A special case occurs when the EMO button is pressed on the unit. When pressed, an error message will be displayed, and a CLEAR button appears. The system opens the EMO relays and signals the error to the client.

At this point the only available action is to move the keyswitch back to the PREP or OFF position, unlatch the EMO, press CLEAR on the touchscreen, and restart the entire setup process from the Prep state. The user authorization does not need to be retransmitted by the

client. If the system was delivering beam, then the session is terminated and cannot be restarted.

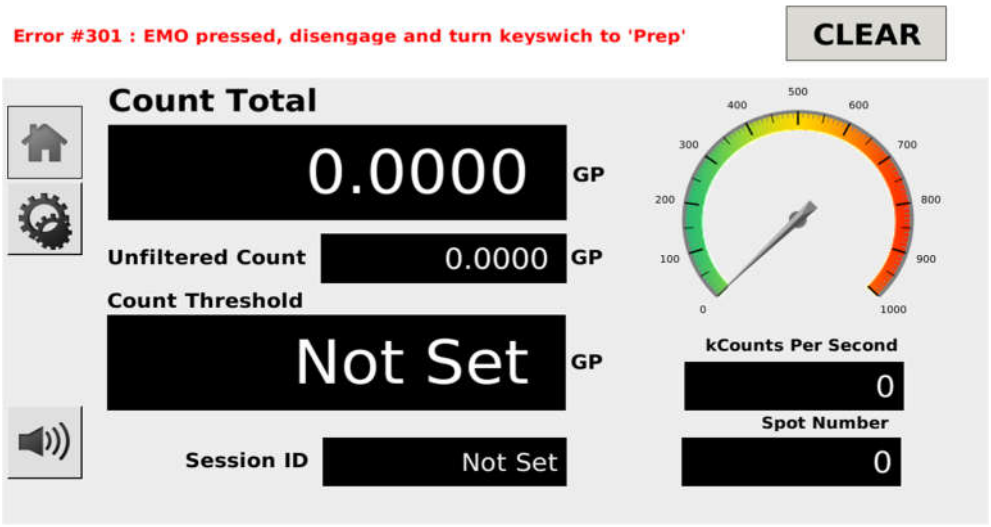



**Figure 33 - CM100 Emergency Off**

## 14.9 Moving the Keyswitch off the TREAT position during Beam On State

During the Beam On state, until the client notifies the CM100 that the treatment is finished, the therapist should not normally turn the keyswitch off the TREAT state. Doing so will cause the error “Keyswitch moved during BeamOn state” to be displayed, revoking the permit, session ID, and Max threshold. The therapist must turn the key back to PREP and press the CLEAR button at the top right of the touchscreen.

# 15 Connectors

## 15.1 Rear Panel

All connections for the CM100 are located on the rear panel, shown in the image below.

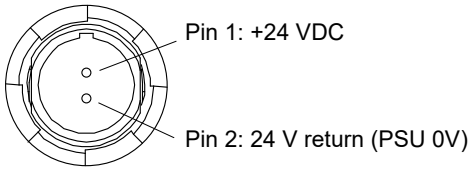

**Figure 34 - CM100 rear panel**

### 15.1.1 **Ground lug**

M4 threaded stud. To mate with M4 ring lug.

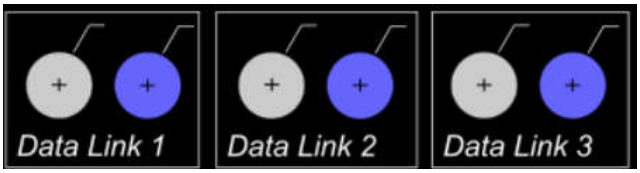
### 15.1.2 **Power input, 24 VDC**

Two-pin Redel PXG.M0.2GG.NG female. To mate with Redel PAG.M0.2 type or PFG.M0.2 type free plugs. Suitably terminated 24 V power supplies and leads are available from Pyramid Technical Consultants, Inc.




### 15.1.3 **Data links**

Six HFBR ST bayonets suitable for 1 mm plastic or 200 µm silica fiber. 664 nm (visible red) light. Dark casing = receiver, light casing = transmitter.



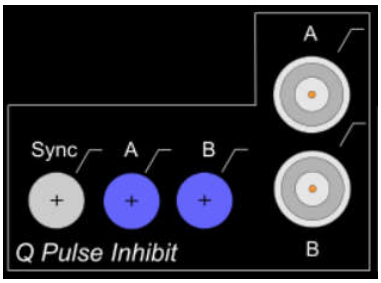

Data Link 1 is used by the CM100 to intercept synchronization messages from the Pyramid Scan Dose system. This provides the spot information and a means to determine that the system is active. Note that it is not necessary to connect the output fiber if the synchronization signal is repeated with an X14 device.

Data Link 2 and Data Link 3 are provided for future enhancements.

### 15.1.4 **Q Pulse inhibit**

Three HFBR ST bayonets suitable for 200 µm core step index silica fiber. 664 nm (visible red) light. Dark casing = receiver, light casing = transmitter.

Two Lemo coax 00 jack (female). Input termination 2.5 kohm.

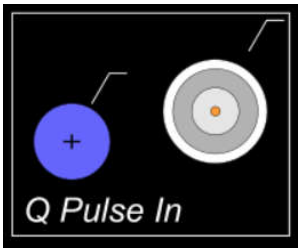



The pulse inhibit is implemented via fiber (inputs A and B) or COAX (inputs A and B), depending upon the setting of the configuration switches located on the bottom of the unit. Only one input is required to inhibit the pulse counting. The Sync connection is not used.

### 15.1.5 **Pulse in**

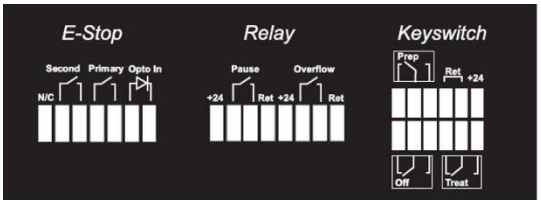
One HFBR ST bayonet suitable for 200 µm core step index silica fiber. 664 nm (visible red) light. Dark casing = receiver, light casing = transmitter.

One Lemo coax 00 jack (female). Input termination 2.5 kohm.




The pulse input is implemented via fiber or COAX input, depending upon the setting of the configuration switches located on the bottom of the unit.

### 15.1.6 **Interlocks**




**Emergency stop**

Phoenix 1827910 7-position 3.81 mm. Locking mating connector Phoenix 1851287 (supplied).

Emergency off switch contacts. Opto-coupled digital input.

| | | | |
|---|---|---|---|
| 1 | n/c | 5 | Switch contact |
| 2 | Redundant contact | 6 | Opto input anode (1 kΩ) |
| 3 | Redundant contact | 7 | Opto input cathode (1 kΩ) |
| 4 | Switch contact | | |

**Relay**

Phoenix 1827923 8-position 3.81 mm. Locking mating connector Phoenix 1851290 (supplied).
Contact closure indication of pause state and counter exceeded limit state.

| | | | |
|---|---|---|---|
| 1 | +24 VDC out | 5 | +24 VDC out |
| 2 | Pause relay contact | 6 | Count limit relay contact |
| 3 | Pause relay contact | 7 | Count limit relay contact |
| 4 | 24V return | 8 | 24V return |

**Keyswitch**

Phoenix 1787056 12-position 3.5 mm. Locking mating connector Phoenix 1790331 (supplied).
Changeover (SPDT) indication of keyswitch state to remote devices.
Position 1: Off Position 2: Prepare Position 3: Treat (direct connection)

| | | | |
|---|---|---|---|
| 1 | Closed in position 1 | 7 | Closed in position 2 |
| 2 | Position 1 common | 8 | Position 2 common |
| 3 | Open in position 1 | 9 | Open in position 2 |
| 4 | Closed in position 3 | 10 | 24 V rtn |
| 5 | Position 3 common | 11 | 24 V rtn |
| 6 | Open in position 3 | 12 | +24 VDC out |

## 15.2 Bottom Panel

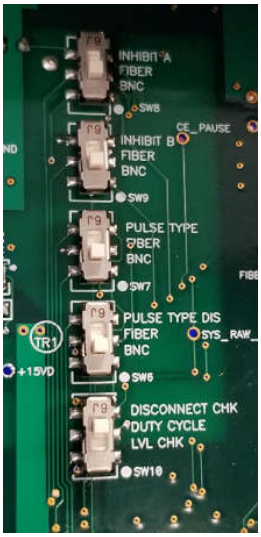
The bottom of the unit has a removable hatch that gives access to various configurations and connects the battery.

### 15.2.1 **Switches**

Dip switches used for configuration.

**ATTENTION**

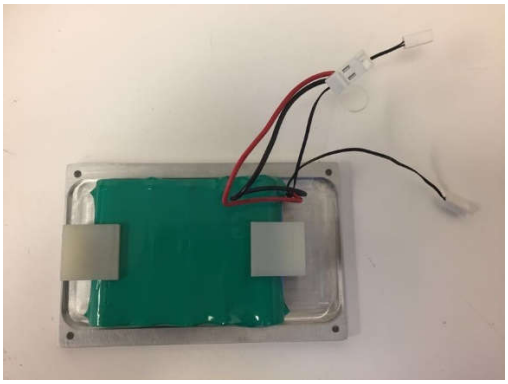
Altering switch settings will affect the operation of the device. Changes should only be made by qualified personnel. If the CM100 is in use in a medical therapy system, then following any change to setup, it is mandatory that the system should be tested and re-certified as fit for its purpose by a qualified person.




| | | |
|---|---|---|
| 1 | INHIBIT A | Selects the Pulse Inhibit input between FIBER or BNC. |
| 2 | INHIBIT B | Selects the Pulse Inhibit input between FIBER or BNC. |
| 3 | PULSE TYPE | Selects the pulse cable type between FIBER or BNC. |
| 4 | PULSE TYPE | Must always be the same setting as 3 above. |
| 5 | DISCONNECT | Always set this to DUTY CYCLE. |

### 15.2.2 **Battery**

The battery is connected to the bottom hatch. It connects to the PCB via three two pin Molex connectors. Each connector is unique, connecting the battery's power, thermistor, and indicator connections to the unit.



# 16 Communications Interface

The CM100 connects to the client via an Ethernet interface. The device acts as an EPICS server, and all information with client applications is exchanged using this protocol. For more information on EPICS please go to the EPICS website at http://www.aps.anl.gov/epics/index.php.

## 16.1 EPICS Process Variables

The PV names will start with the CM100 unit's serial number so that they are unique. The following parameters are supported. Network Configuration

The CM100 uses EPICS communication over standard local area network hardware. Addressing is using the IP4 standard, and it supports static and dynamic (DHCP) address assignment. The device can be configured via the PTC DiagnosticG2, via the serial interface, or by your own host software using the appropriate procedure calls.

Most control and data acquisition systems are set up with fixed addresses assigned by the network administrator. It is also typical to isolate such networks from the internet to prevent unauthorized access, and to allow operation without firewalls which can disrupt communications.

In order for the host computer and the CM100 to communicate, they must be within the same subnet. It is typical to limit a local network to 256 addresses by setting the IP4 subnet mask to 255.255.255.0. Then the CM100 and the host must have the first three bytes of their addresses common, and must differ in the last byte. For example, the host could be 192.168.100.11 and the I128 at 192.168.100.20. The last byte must also not conflict with any other devices on the same subnet. Addresses with last byte 0 and 255 are reserved for special functions in TCP/IP. See the section on "File Setups" for information on changing the IP address of the unit.

Following is a list of all available process variables:

| PV Name | Description | Direction | Type |
|---|---|---|---|
| **[CM100serial#]_version** | Version number, in the form:<br>[byte0].[byte1].[byte2].[byte3]<br>To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_arm_heartbeat** | Heartbeat counter incremented by master CM100 service process running on ARM. This value should increment at a high rate and will overflow. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_cm100_heartbeat** | Heartbeat counter incremented by the master CM100 state machine process. | R | Integer32 |
| **[CM100serial#]_pru0_heartbeat** | Heartbeat counter incremented by slave CM100 service process running on PRU0. This value should | R | Integer32 |

| | | | |
|---|---|---|---|
| | increment at a high rate and will overflow. To be read-only for all clients. | | |
| **[CM100serial#]_pru1_heartbeat** | Heartbeat counter incremented by slave CM100 service process running on PRU1. This value should increment at a high rate and will overflow. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_pause** | State of physical PAUSE button. To be read/write for local CM100 UI, read-only for client applications. | R | Boolean |
| **[CM100serial#]_start** | State of physical START button. To be read/write for local CM100 UI, read-only for client application. | R | Boolean |
| **[CM100serial#]_emo** | State of physical EMO button. To be read-only for all clients. | R | Boolean |
| **[CM100serial#]_pulse_discon_hw** | Cable disconnect state, as detected by hardware. | R | Boolean |
| **[CM100serial#]_ready_permit** | Permit issued by user that allows the CM100 to transition out of the PREPARATORY state.<br><br>0x55555555 = PERMIT GRANTED<br>other = PERMIT NOT GRANTED<br><br>Other informational codes (ALL PERMIT NOT GRANTED):<br>0x11111111 = Control system process paused.<br>0x22222222 = Control system process finished. | RW | Integer32 |
| **[CM100serial#]_session_id** | User-defined session ID.<br>-1 = INVALID<br>other = VALID<br>Note: Changing this value will reset the treatment MU/GP integrator: [CM100serial#]_treat_count_mu | RW | Integer32 |
| **[CM100serial#]_cumulative_spot** | Cumulative spot number, read from ScanDose fiber connection.<br>-902 = Fiber timeout. | R | Integer32 |

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|---|---|---|---|
| | -901 = Fiber message corrupt.<br>-900 = Fiber system uninitialized.<br>other = Valid spot number. | | |
| **[CM100serial#]_spot_count_enabled** | 1: Spot count check enabled<br>0: Spot count check disabled | R | Boolean |
| **[CM100serial#]_count_reset** | Reset count command. Calling this command will reset the unfiltered and filtered pulse count integrators to 0. To be written by client application or local UI. Argument ignored. | RW | Boolean |
| **[CM100serial#]_key_position** | State of keyswitch position readback. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_relay1** | Relay 1 command | RW | Boolean |
| **[CM100serial#]_relay2** | Relay 2 command | RW | Boolean |
| **[CM100serial#]_count_unfiltered** | Snapshot of unfiltered pulse count integrator, lower 32 bits. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_count_unfiltered_ovf** | Snapshot of unfiltered pulse count integrator, upper 32 bits. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_count_filtered_qep** | Snapshot of filtered pulse count integrator (QEP), lower 32 bits. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_count_filtered_ovf_qep** | Snapshot of filtered pulse count integrator (QEP), upper 32 bits. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_count_filtered_dm** | Snapshot of filtered pulse count integrator (DMTimer), lower 32 bits. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_count_filtered_ovf_dm** | Snapshot of filtered pulse count integrator (DMTimer), upper 32 bits. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_count_rate** | Snapshot of filtered/unfiltered (configurable) pulse count rate. To be read-only for all clients. | R | Integer32 |
| **[CM100serial#]_prescaler** | Prescaler value, in units of MU/pulse. | R | Float |
| **[CM100serial#]_treat_count_mu** | Snapshot of treatment dose integrator, in units of MU/GP. | R | Float |

| | | | |
|---|---|---|---|
| **[CM100serial#]_treat_count_mu_unfiltered** | Snapshot of treatment dose integrator, in units of MU/GP, for unfiltered count | R | Float |
| **[CM100serial#]_treat_count_max** | Maximum MU/GP threshold for the irradiation (typically 120% of expected delivery). | RW | Float |
| **[CM100serial#]_count_user_units** | User Units of display counts. Will be either MU or GP | R | String |
| **[CM100serial#]_audio_ppt** | Number of pulses in the audio pulse integrator required to output an audio tick. The audio pulse integrator is reset after this threshold is reached. This parameter controls the audio tick rate to pulse rate relationship. | RW | Integer32 |
| **[CM100serial#]_audio_spt** | Number of audio samples output per tick. This number is a factor in volume and tick sound. | RW | Integer32 |
| **[CM100serial#]_audio_tone_tick** | Audio tick sound selection.<br>0 = Simple tick<br>1 = Sine wave tick | RW | Boolean |
| **[CM100serial#]_audio_tone_tick_freq** | Frequency of audio sine wave tick. This is only applicable if audio_tone_tick == 1. | RW | Integer32 |
| **[CM100serial#]_audio_int_period** | Polling period for the audio process, in ms. The process will examine the audio pulse integrator at this period. | RW | Integer32 |
| **[CM100serial#]_audio_volume** | Volume level (0-100%) | RW | Integer32 |
| **[CM100serial#]_func_state** | Functional state of CM100. See state machine and sequence diagrams for more details. To be read-only for all clients.<br>OFF = 0<br>STANDBY = 1<br>PREP = 2<br>READY = 3<br>BEAM ON = 4 | R | Integer32 |
| **[CM100serial#]_op_state** | Operational state of CM100. See state machine and sequence | R | Integer32 |

| | | | |
|---|---|---|---|
| | diagrams for more details. To be read-only for all clients.<br><br>RUNNING = 0<br>SERVICE = 1<br>ERROR = 2 | | |
| **[CM100serial#]_error** | Array of error information:<br>[0] = Error Code<br>[1] = 1: Clearble error<br>0: Blocking error | R | Float[3] |
| **[CM100serial#]_op_clear_error** | Clear Operational Error command. Argument ignored. | RW | Boolean |
| **[CM100serial#]_prepared_conditions** | Boolean value indicating if the Prepared Conditions have been met and the user can turn the keyswitch to Treat | R | Boolean |
| **[CM100serial#]_auth_code** | Authorization code from external control system to CM100. Integer bitmask format. See User Authorization for details.<br><br>BIT0 = CLINICAL AUTH<br>BIT1 = SERVICE AUTH | RW | Integer32 |
| **[CM100serial#]_control_system_heartbeat** | Heartbeat counter incremented by master CMS service process to monitor connection between DCS and CM100. This value should increment at a high rate and will overflow. To be written by CMS. | RW | Integer32 |
| **[CM100serial#]_ control_system_connected** | Boolean value indicating state of heartbeat connection to external control system.<br>TRUE = CONNECTED<br>FALSE = NOT CONNECTED | R | Boolean |
| **[CM100serial#]_ip_address** | Integer representation of IP address | RW | Integer32 |
| **[CM100serial#]_subnet_mask** | Integer representation of subnet mask | RW | Integer32 |
| **[CM100serial#]_default_gateway** | Integer representation of default gateway | RW | Integer32 |

| | | | |
|---|---|---|---|
| **[CM100serial#]_ethernet_set** | Push down Ethernet settings command. Calling this command will push down the Ethernet's IP address, static/dynamic, subnet mask, and default gateway. To be written by client application or local UI.<br>1 = Set Ethernet Settings<br>0 = Cancel | RW | Boolean |
| **[CM100serial#]_power_disconnected** | 1= AC power connected<br>0 = AC power not connected | R | Boolean |

# 17 Fault Finding

| Symptom | Possible Cause | Confirmation | Solution |
|---|---|---|---|
| Device will not boot or communicate | Damage to CM100. | | Contact Pyramid Technical Consultants, Inc. |
| | Failed firmware update. | | Contact Pyramid Technical Consultants, Inc. |
| | Network IP addresses between CM100 and client not compatible. | Check network addresses and IP masks are compatible. | Change addresses or configuration as needed. |
| | Duplicate Ethernet address of CM100. | | Change CM100 address. |
| Pulses do not count | Bad pulse input cable. | Check “Cable LED” on GUI indicating that the cable is connected properly. | Replace cable. |
| | Broken fiber optic receiver used for incoming pulses. | Examine if there is any physical damage to receiver or if it is loose on the PCB. | Send unit back for repair. |
| | Broken fiber optic transmitter on client system used for pulse inhibit. | Look at pulse inhibit source and confirm it is stuck in the lit state. | Fix pulse inhibit transmitter. |
| | Damage to CM100. | | Contact Pyramid Technical Consultants, Inc. |
| Pulse count is not accurate | Improperly terminated BNC cable. | Verify cable termination. | Terminate cable with 50 ohm. |

| | | | |
|---|---|---|---|
| | Interference from noise sources. | Investigate noise sources. | Eliminate noise source or reposition pulse input count cable. |
| | Client system is operating in different mode from CM100 display (MU/Gp). | Examine client system mode vs. label on CM100. | Set label on CM100 display to match client system mode. |
| | Damage to CM100. | | Contact Pyramid Technical Consultants, Inc. |
| Pulse counts seen when no beam present | Electrometer connected to the CM100 has background offset. | Check raw data from electrometer. | Apply offset correction and/or locate and remove source of offset. |
| | Electrometer connected to the CM100 is detecting noise. | Check raw data from electrometer. | Remove source of noise. |
| System does not start when pressing the “Start” button. | Key switch not placed in “TREAT” position. | Examine key position. | Follow workflow procedures. |
| | Client has not properly loaded parameters and authorization due to network or other client issues. | Check network connection and client software. | Fix network connection or resolve client software issues. |
| | Damage to CM100. | | Contact Pyramid Technical Consultants, Inc. |
| System does not pause when pressing the “Pause” button during a treatment. | Damage to CM100. | | Contact Pyramid Technical Consultants, Inc. |
| System does not change state as expected when the keyswitch in operated. | Wear to the switch contacts. | Check time of last replacement. | Replace switch assembly – see section 18.4. |

# 18 Maintenance

There are no user-serviceable parts inside the CM100 apart from the battery pack which can be replaced through its service panel without opening the main case.

## 18.1 Operation check

A regular quality assurance check should be made to check that the following function as expected:

- Audio tone is clearly audible in the working environment
- Interlock relay (beam is stopped) opens on count overflow
- Disconnected pulse signal cable is detected by the unit
- Pause button functions (beam is stopped)
- Turning keyswitch from Treat back to Prep stops beam delivery
- EMO button functions (primary contacts open, connected systems are disabled)

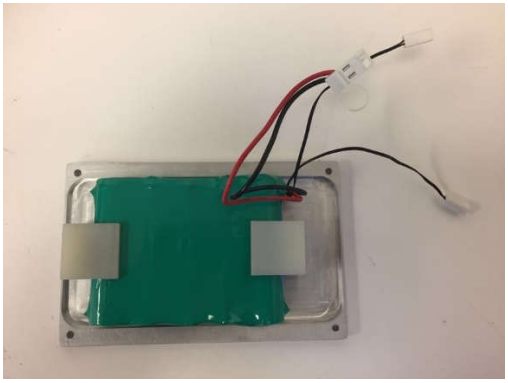
The checks will be embedded in machine QA protocols for a particular facility.

## 18.2 Checking the Battery

To perform the battery check, remove the power cord to the CM100 with the unit powered on. Observe after 30 minutes that the system behaves normally. Reconnect the power cord.

## 18.3 Battery Pack Replacement

To replace the battery pack, unscrew the four screws on the bottom panel of the unit.



Remove the three Molex connectors connecting the battery to the PCB. Attach the new battery by reattaching the Molex connectors. Allow the battery to charge up for four hours, then check the battery as in the section “Checking the Battery”.

It is recommended to replace the battery pack every three years or less.

## 18.4 Replacing the keyswitch

The CM100 keyswitch is rated for 10,000 operations. In a treatment room delivering 15 fractions per day, this would correspond to around one year of operation. Pyramid recommends that the switch assembly is replaced once per year in an active treatment room for this reason. The switch itself is APEM type LK69NB126N3, but Pyramid supplies an assembly with the connecting cable attached.

### 18.4.1 **Tools and materials required**

- Replacement CM100 key assembly, sales code CM100KSW.
- 3mm hex key
- Screw-driver
- Wire cutter tool
- Large channel-lock pliers (adjustable wrench)
- Flash-light (as necessary)

### 18.4.2 **Procedure**

This procedure covers CM100 units manufactured prior to 2022. Units after that mount the switch on a removable plate which avoids the need to open the case.

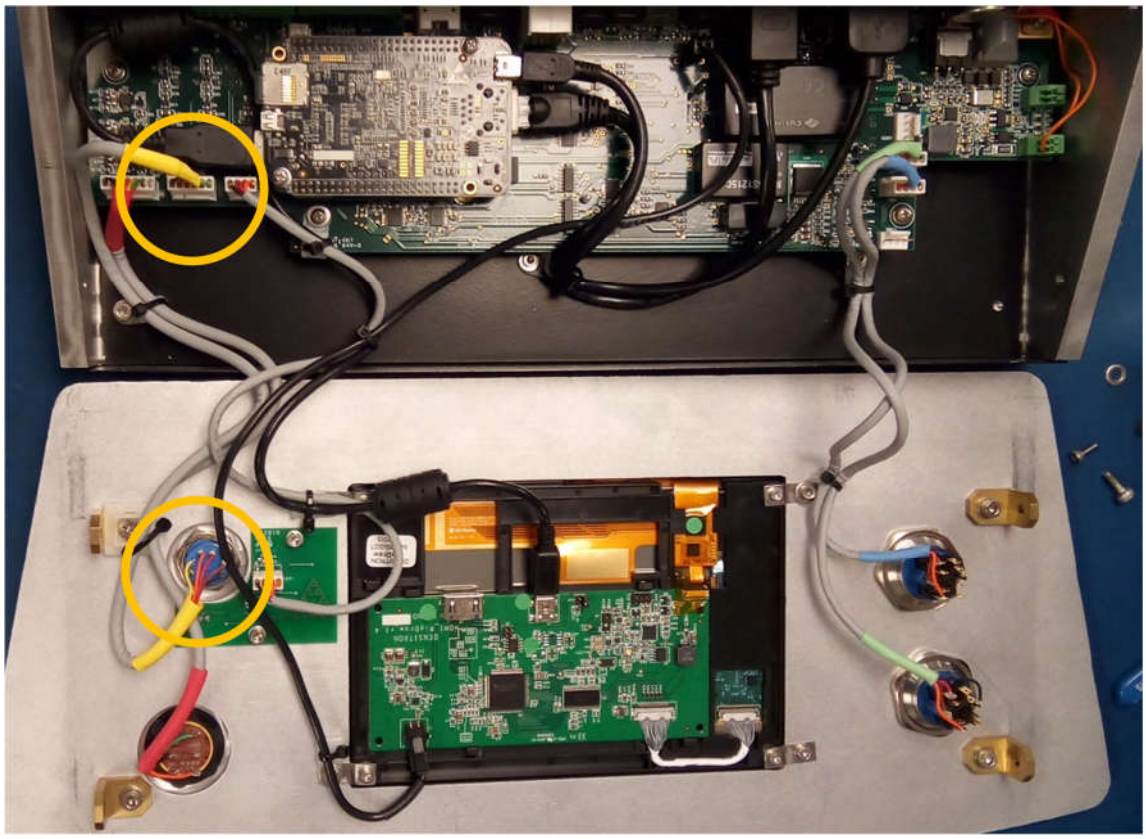
1) Unplug the 24 V power connector at the back of the CM100.

2) Open the battery hatch on the bottom of the CM100 using and unplug the cable for the battery. The CM100 should now be off.

3) Loosen and remove the four M4x10 hex head screws from the sides of the CM100.

4) Very carefully, lift the top panel of the CM100 from the chassis base. Without stretching or straining any cable,turn the top panel over and lay it in front of the base.

5) Locate the keyswitch cable and where it connects to the main circuit board at a 6-pin header header connector. The cable is identified by yellow heatshrink.



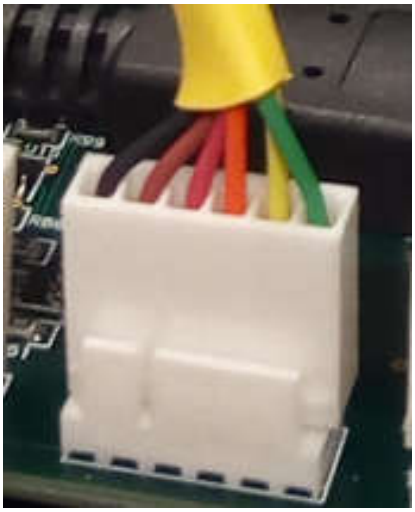
6) Using the wire cutter as necessary, remove any cable ties that are holding the keyswitch cable, taking great care not to cut the cables.

7) Using the channel-lock pliers, loosen and remove the large nut holding the keyswitch to the top panel.

8) Gently remove the old keyswitch and cable assembly by passing it through the hole in the top panel and put aside.

9) Thread the new keyswitch cable through the top panel and lock it in place with the large nut. Make sure the key orientation is correct with respect to the front panel before tightening down the nut with the channel-lock pliers.

10) Connect the header connector at the end of the keyswitch cable to the circuit board.



11) Use small cable ties or Velcro strip to organize the cable so that it will bend correctly with the other cables when the top panel is closed.

12) Place the top panel back on the CM100 chassis. Take care not to damage the sensitive RF ground fingers at the front of the chassis.

13) Align the holes in the chassis with the threaded holes on the top panel (a flashlight might help to seethat the holes are aligned) and run in all four screws (2 on each side).

14) Tighten the four screws.

15) Reconnect the battery cable

16) Close and secure the battery access panel

17) Connect the 24 V power cable to the CM100 and wait for the CM100 to power up.

18) Perform QA tests as required by local working practice to confirm that the system is fully functional.

# 19 Returns Procedure

Damaged or faulty units cannot be returned unless a Returns Material Authorization (RMA) number has been issued by Pyramid Technical Consultants, Inc. If you need to return a unit, contact Pyramid Technical Consultants at support@ptcusa.com, stating

- model
- serial number
- nature of fault

An RMA will be issued, including details of which service center to return the unit to.

# 20 Support

Manual and software driver updates are available for download from the Pyramid Technical Consultants website at **www.ptcusa.com**. A secondary site can be found at **www.ptceurope.com**. Technical support is available by email from support@ptcusa.com. Please provide the model number and serial number of your unit, plus relevant details of your application.

# 21 Disposal

We hope that the CM100 gives you long and reliable service. The CM100 is manufactured to be compliance with the European Union RoHS Directive 2002/95/EC, and as such should not present any health hazard. Nevertheless, when your CM100 has reached the end of its working life, you must dispose of it in accordance with local regulations in force. If you are disposing of the product in the European Union, this includes compliance with the Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC. Please contact Pyramid Technical Consultants, Inc. for instructions when you wish to dispose of the device.

# 22 Revision History

The release date of a Pyramid Technical Consultants, Inc. user manual can be determined from the document file name, where it is encoded YYMMDD. For example, CM100_UM_080105 would be a CM100 manual released on 5 January 2008.

| ***Version*** | ***Changes*** |
|---|---|
| CM100_UM_180228 | First general release. |
| CM100_UM_200423 | Corrected relay connector pin function table<br>Minor corrections throughout. |
| CM100_UM_220223 | Added keyswitch replacement to maintenance section. |

# DOCUMENT APPROVAL

This document has been reviewed and approved by the following individuals:

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